ERDC/GSL TR-16-27

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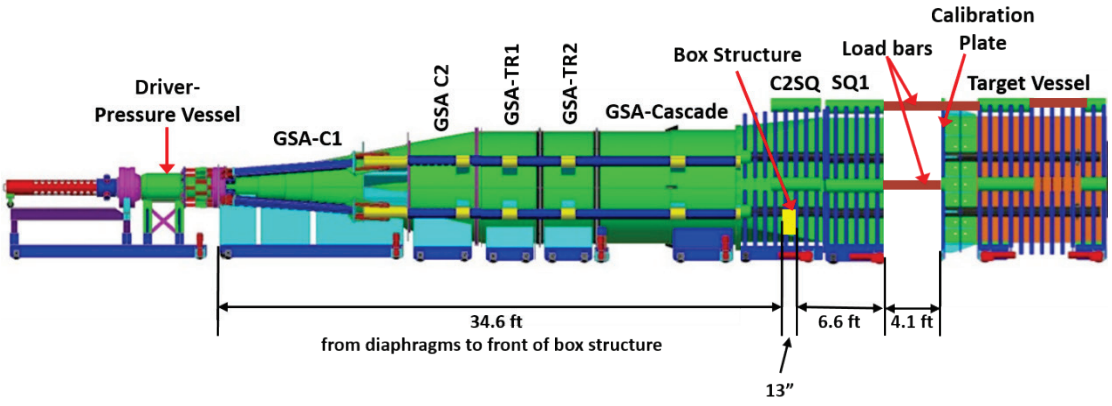
Blast Load Simulator Experiments for Computational Model Validation

Report 3

Carol F. Johnson, Andrew T. Barnes, and James L. O'Daniel

July 2017



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Carol F. Johnson, Andrew T. Barnes, and James L. O'Daniel

Geotechnical and Structures Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
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Report 3 of a series

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Prepared for Defense Threat Reduction Agency
Fort Belvoir, VA 22060

Under Project 444856, "Nuclear Airblast and Thermal Environments Testing and Modeling"

Abstract

The Department of Defense needs the capability to accurately predict airblast environments produced by explosive detonations and their interaction with geometrically complex objects that create complex flow fields, such as buildings, bridges, dams, etc. First-principles computer codes are typically used to generate high-fidelity simulations of these explosive events and their effects. These codes are continuously improving, but still require validation against experimental data to establish confidence in the results produced by the simulations. This report describes a set of replicate experiments in which a small, non-responding steel box-type structure was installed at varying obliquities and subjected to a simulated blast loading in a Blast Load Simulator (BLS) to provide pressure-time data at several locations on the surfaces of the structure. The BLS is a highly tunable, compressed-gas-driven, closed-end shock tube designed to simulate blast waveforms for explosive yields up to 20,000 lb of TNT equivalent at a peak reflected pressure up to 80 psi and a peak reflected impulse up to 1,100 psi-msec. Pressure and impulse waveforms are presented, and comparisons were made among the replicated experiments to evaluate repeatability. The uncertainty in the experimental pressures and impulses was evaluated by computing 95% confidence intervals on the results.

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Preface

This research was conducted for the Defense Threat Reduction Agency under Project 444856, “Nuclear Airblast and Thermal Environments Testing and Modeling”. The Technical Monitor was Dr. James L. O’Daniel.

The work was performed by the Structural Mechanics Branch (GSM) and the Research Group (GSR) of the Geosciences and Structures Division (GS), U.S. Army Engineer Research and Development Center, Geotechnical and Structures Laboratory (ERDC-GSL). At the time of publication, Bradford A. Steed was Chief, CEERD-GSM; James L. Davis was Chief, CEERD-GS; and Pamela G. Kinnebrew, CEERD-GZT, was the Technical Director for Survivability and Protective Structures. The Deputy Director of ERDC-GSL was Dr. William P. Grogan, and the Director was Bartley P. Durst.

COL Bryan S. Green was the Commander of ERDC, and Dr. David W. Pittman was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
inches	0.0254	meters
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms

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1 Introduction

1.1 Background

The U.S. Department of Defense (DOD) needs the capability to accurately predict the airblast environment produced by explosive detonations and its interaction with geometrically complex objects that create complex flow fields, such as buildings, bridges, dams, and many others. First-principles computer codes are typically used to generate high-fidelity simulations of these explosive events and their effects. These codes are continuously improving, but they still require validation against experimental data to establish confidence in the simulation results specific to their intended use.

One method for providing experimental data for computational model validation is to use a blast load simulator, such as a shock tube, to produce a simulated high-explosive blast environment. Generally, a shock tube can provide a repeatable blast environment at a significantly lower cost than conducting field experiments using explosives. Repeated experiments are often necessary to quantify the uncertainty in the experimental results for validating computational models.

1.2 Objective

The objective of this effort was to conduct a set of repeated experiments in the U.S. Army Engineer Research and Development Center (ERDC) Blast Load Simulator (BLS) to measure the pressure loading on a non-responding box-type structure at varying obliquities located in the flow of the BLS simulated blast environment for use in evaluating computational models.

1.3 Approach

To meet the objective of this effort, a series of five replicate experiments at three obliquities were conducted in the BLS, using what is referred to as the 8x8 BLS configuration (Dallriva et al. 2016a). In order to reduce the influence of the reflected pressure from the calibration plate on the recorded data, the BLS configuration was modified by introducing a 4-ft gap prior to the target vessel. The non-responding structure was installed

in the BLS at a distance far enough downstream of the driver and near the reflecting target plate to provide increased testing time undisturbed by the interface (contact surface) between the driver gases and the driven gases. Otherwise, the contact surface impinging on the structure would result in turbulent effects that significantly reduce experiment repeatability. Data from the five experiments at each obliquity were used to calculate 95% confidence intervals in the results. The confidence intervals account for uncertainties associated with any small unknown or uncontrollable variations in experiment setup and conditions and for any inherent random variability in the dynamic environment produced in this BLS experimental process.

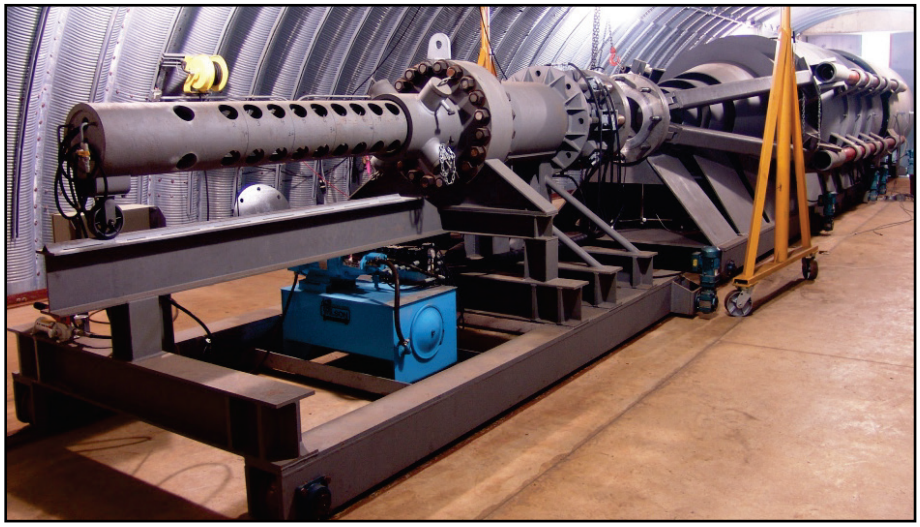
Pressure gauges were installed on the four sides and top of the structure, in the wall of the BLS near the structure, and in a fixed steel reflecting plate (referred to as the calibration plate) at the end of the BLS, all for recording pressure vs. time at the gauge locations. Data plots are provided that include pressure-time and impulse-time histories, and a few comparison plots are provided for visual evaluation of test repeatability.

2 Experiment Descriptions

2.1 Blast load simulator

The ERDC BLS (Figure 1) is a highly tunable, compressed-gas-driven shock tube designed to simulate blast waveforms for explosive yields up to an equivalent of 20,000 lb of TNT at a peak reflected pressure up to 80 psi and a peak reflected impulse up to 1,100 psi-msec.[1] The BLS has been used to evaluate the blast response of various structural test articles including windows, walls, and structural retrofit systems. It can simulate blast waveforms from very low pressures (1 to 2 psi) related to failures of conventional annealed glass and hollow concrete masonry unit walls, to higher blast pressures required to evaluate the performance of protective construction methods.

Figure 1. ERDC Blast Load Simulator (BLS).



A recent addition to the BLS, referred to as the 8×8 configuration shown in Figure 2, includes a section to transition from the circular cross section that begins just downstream of the driver to a square cross section for testing 8-ft by 8-ft-square test articles, such as windows and walls. A detailed description of the BLS is provided in the first report of this series (Dallriva et al. 2016a).

[1] Johnson, C. F., and L. Simmons. 2008. *Blast load simulator/Shock tube testing facilities in the United States*. Information Paper. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Figure 2. View from exterior of 8x8 configuration.

2.2 Single-structure experiments in the BLS 8×8 configuration with 4-ft gap at varying obliquities

The BLS configuration for the set of experiments described herein is a modification of that described in the second report of this series (Dallriva et al. 2016b). The configuration was modified by the addition of a 4-ft gap between the end of the square section and the target vessel. This gap was introduced to significantly reduce the magnitude of the pressure that reflects from the calibration plate and back to the box structure. It also provided more time for the initial pressure to engulf the structure and decay prior to the reflection from the calibration plate impinging on the structure from behind.

Replicate experiments were conducted in the BLS using the 8×8 configuration with a 4-ft gap at obliquities of 0, 30, and 45 degrees. Obliquity of zero degrees was defined as the front face of the structure oriented face-on to the driver gases, as described in the second report of this series (Dallriva et al. 2016b). The obliquity was varied by rotating the structure about its center point such that the center point of the box was maintained at the same location within the BLS for all experiments. An elevation drawing of this BLS configuration at 0-degree obliquity is shown in Figure 3, a photograph of the gap introduced between the square section and the target vessel is shown in Figure 4, and a cross-section view from inside the GSA cascade section of the BLS looking towards the target vessel showing the vertical location of the box structure is shown in Figure

5. The top of the box structure was located 19.5-in. below the horizontal centerline of the BLS. The centerline of the BLS is always defined with respect to the centerline of pressure vessel, regardless of asymmetry of the C2SQ section observable in Figure 3. The box structure was 13-in. x 13-in. x 18-in. tall as shown in Figure 6. The structure was mounted on an 8.5-in.-tall steel pedestal welded to the bottom of the BLS. Figure 7 shows a photograph inside the BLS viewing the structure mounted on the steel pedestal at 30-degree obliquity and the steel calibration plate. The faces of the structure were defined as follows: the front side of the structure faces the pressure vessel at 0-degree obliquity, and the rear side faces the calibration plate at 0-degree obliquity. The left and right sides of the structure are defined at 0-degree obliquity looking upstream from the target vessel towards to the pressure vessel. Plans views of the structure at each obliquity showing the rotation and location of each side relative to the flow are shown in Figure 8. Figures 9 and 10 show the structure and direction of rotation for 30- and 45-degree obliquities, respectively.

Instrumentation included 3 pressure gauges mounted on the steel calibration plate, 2 pressure gauges mounted in the wall of the BLS, and 25 pressure gauges mounted on the box structure. Figure 11 shows the gauge layout on the calibration plate. Figure 12 shows the gauge layout on the side walls of the BLS in the square and C2SQ sections. Figures 13 through 17 show the gauge layouts on the surfaces of the box structure and the direction of flow at 0-degree obliquity.

Pressure measurements were made using either Kulite Model HKS-11-375 or XT-190 piezo-resistive pressure transducers. The data were transmitted over shielded mil-spec cable and recorded on a 16-bit Pacific Model 5810 Data Acquisition System. The acquisition system's sample rate was set for 1.0 μsec per point for the pressure measurements. The data after collection were post-processed using filter option four in DPlot software.

In each test, the pressure vessel was pressurized, using air only, to 800 psi. A mechanical striker was used to initiate the pressure release through rupturing of diaphragms. The diaphragms consisted of three layers that included two layers of 0.0160-in. to 0.0350-in.-thick steel and one layer of 0.0170-in. to 0.0240-in.-thick aluminum. A single test used two aluminum diaphragms with a combined thickness of 0.02925-in.

Figure 3. BLS 8x8 configuration with box structure and 4-ft gap.

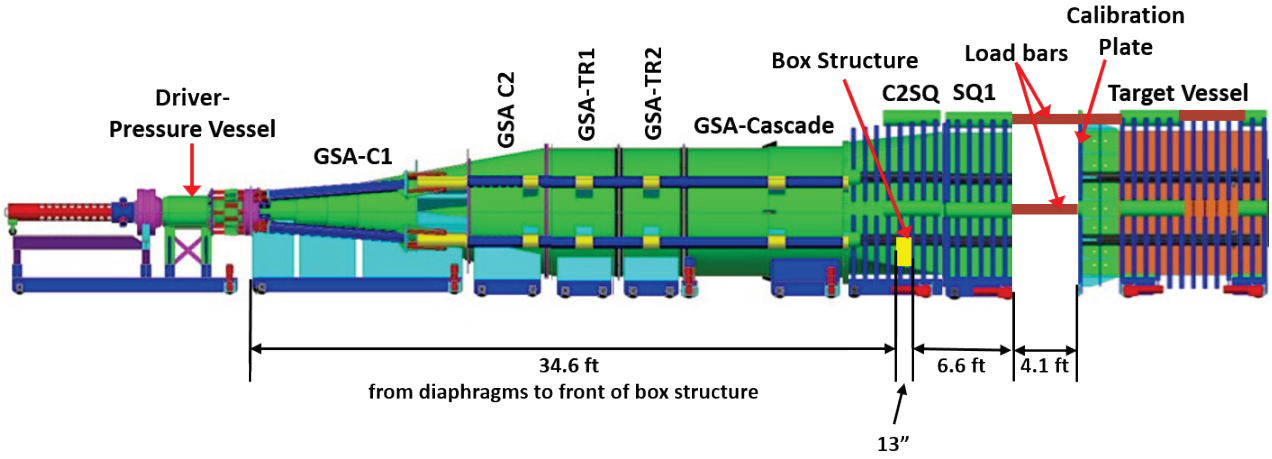


Figure 4. BLS 8x8 configuration with 4-ft gap.

Figure 5. BLS cross section showing the location of the box structure.

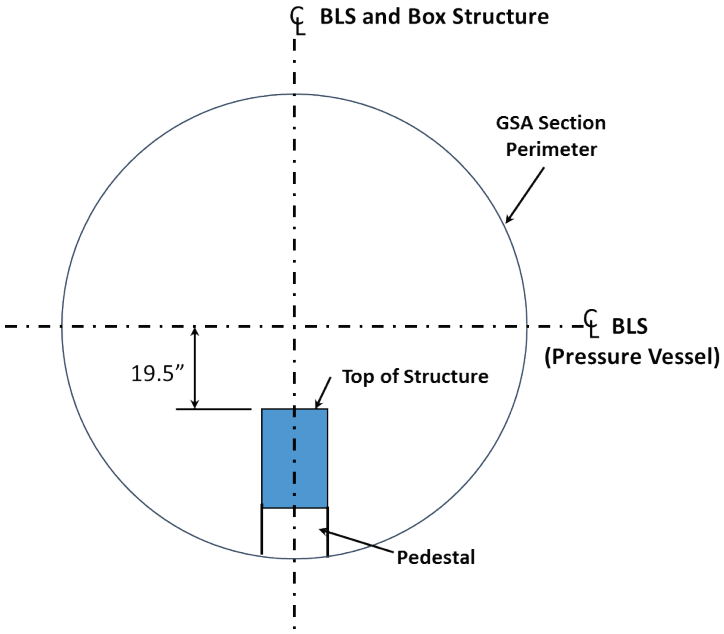


Figure 6. Box structure dimensions.

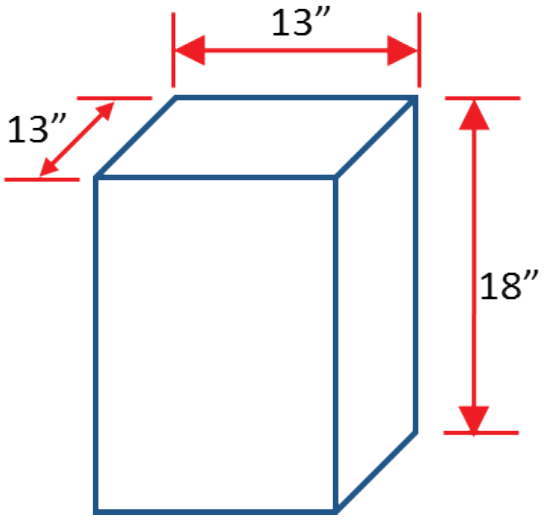


Figure 7. Photograph of the box structure (30-degree obliquity) and calibration plate.

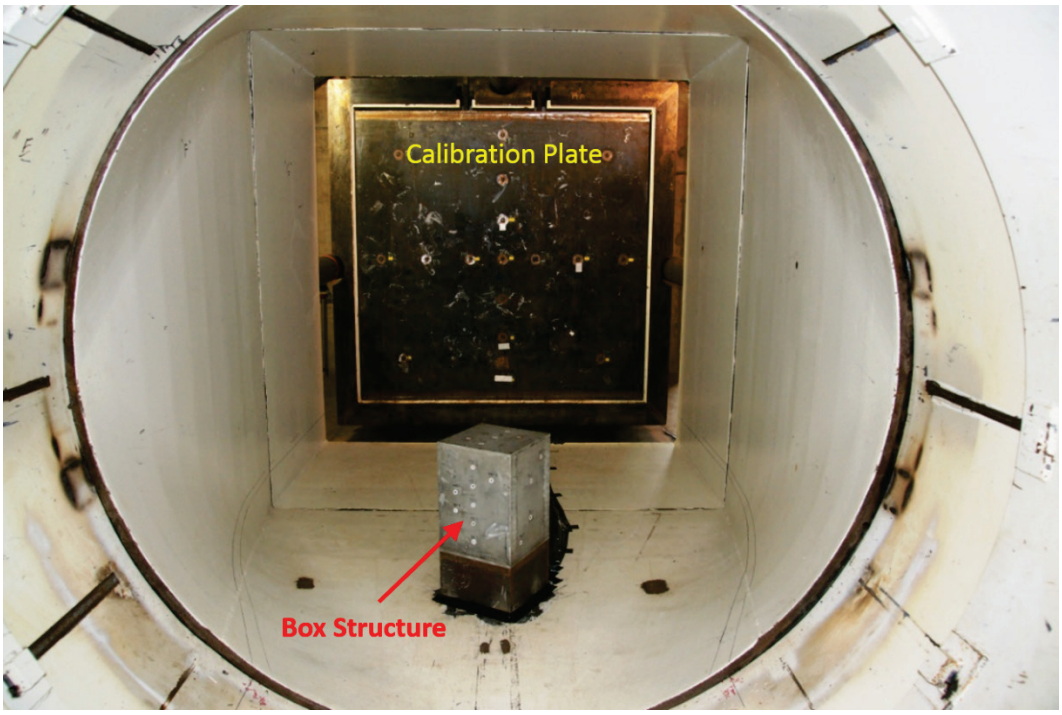


Figure 8. Plan view of structure at (a) 0-degree, (b) 30-degree, and (c) 45-degree obliquities.

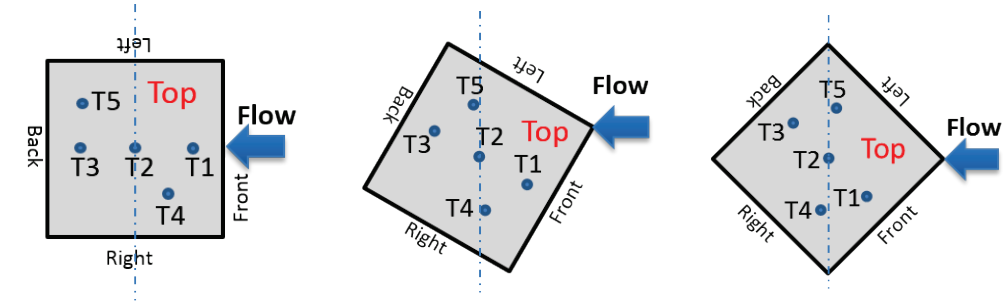


Figure 9. Structure rotated to 30-degree obliquity.

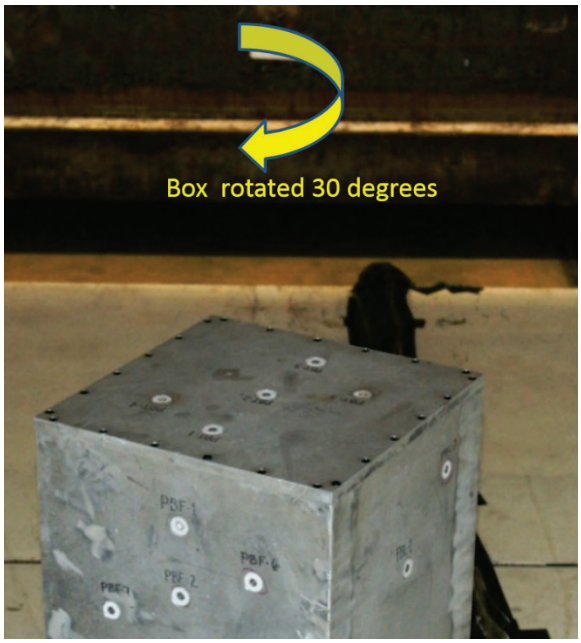


Figure 10. Structure rotated to 45-degree obliquity.

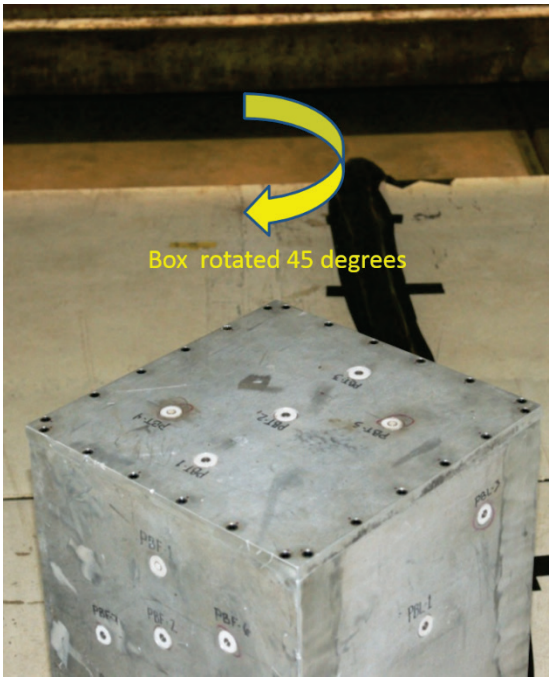


Figure 11. Gauge layout on the calibration plate.

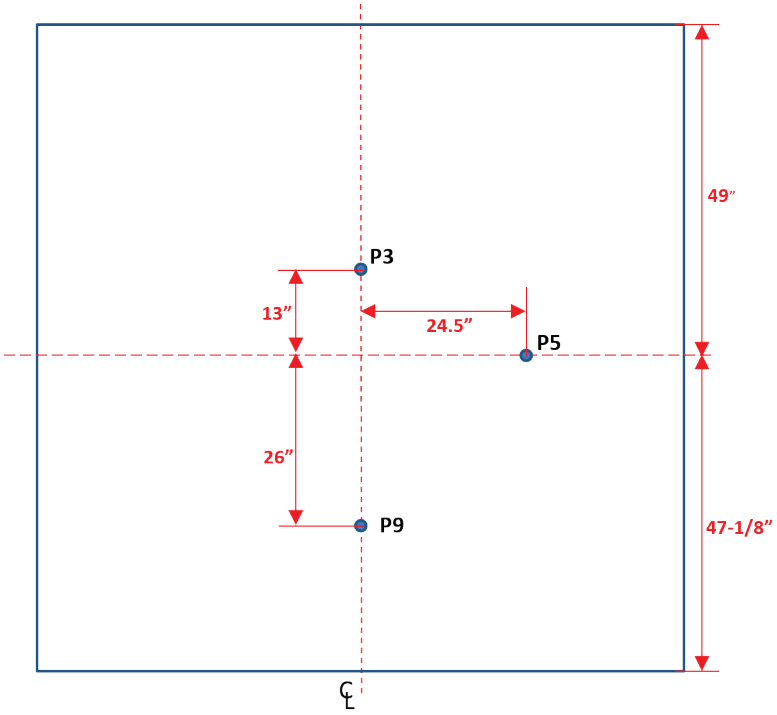


Figure 12. Gauge layout on the BLS side walls.

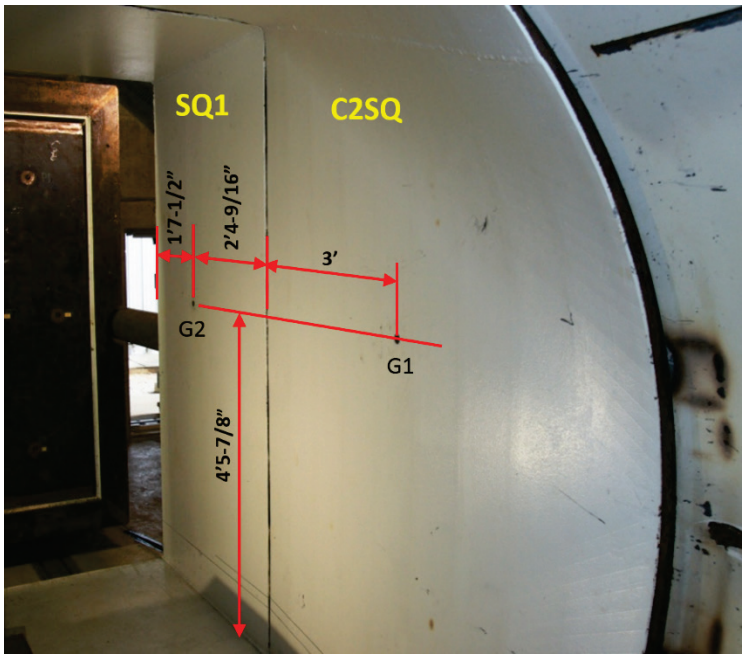


Figure 13. Gauge layout on the front of box structure.

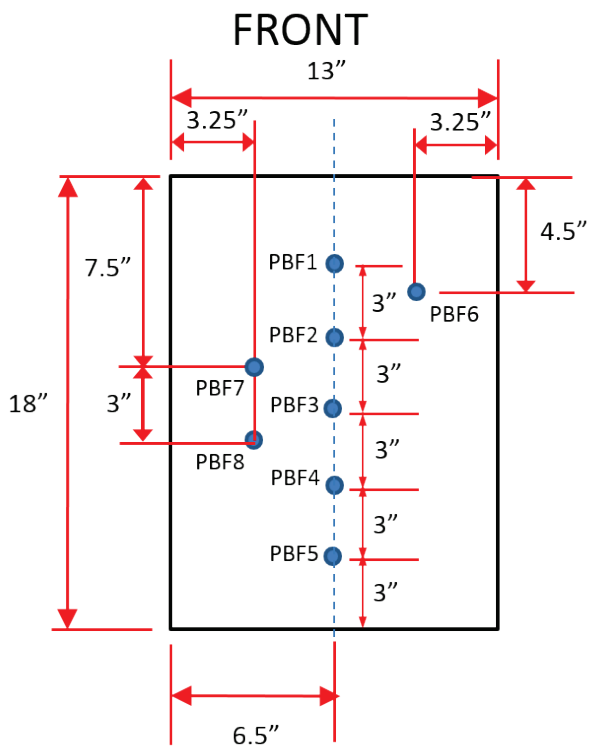


Figure 14. Gauge layout on the back of box structure.

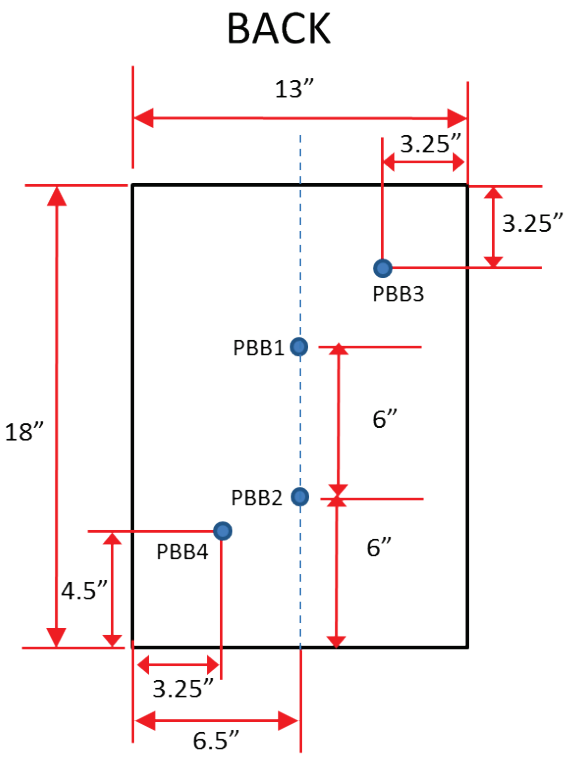


Figure 15. Gauge layout on the top of box structure and direction of flow at 0-degree obliquity.

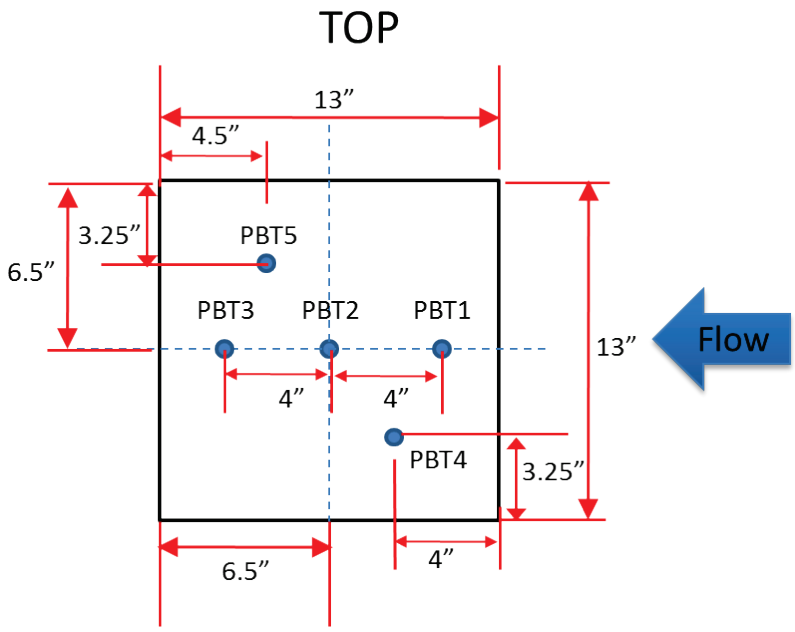


Figure 16. Gauge layout on the left side of box structure and direction of flow at 0-degree obliquity.

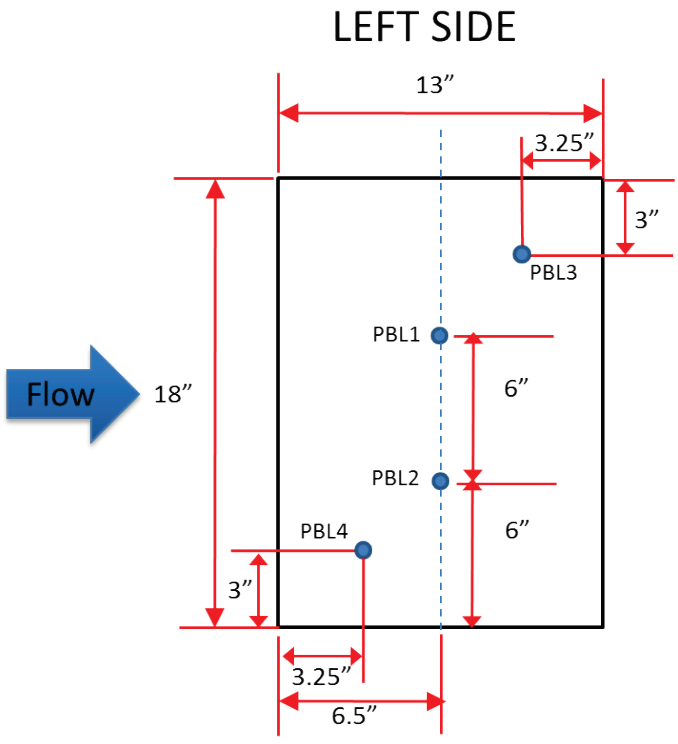
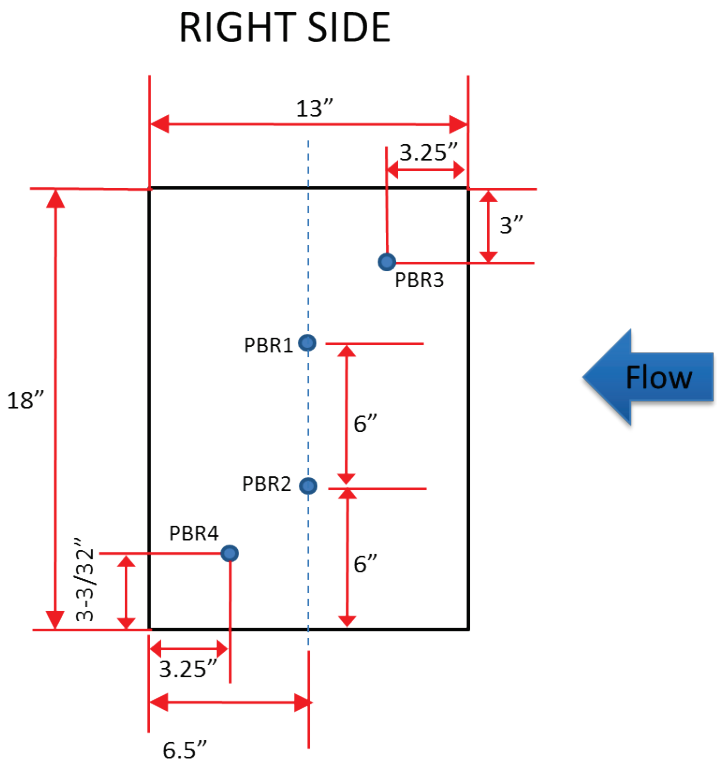


Figure 17. Gauge layout on the right side of structure and direction of flow at 0-degree obliquity.



3 Experimental Results

3.1 Comparison of pressure waveforms

3.1.1 0-degree obliquity

One test at 0-degree obliquity -- test number 4 -- had a burst pressure of 778 psi; the remaining four tests all had a burst pressure of 800 psi. Comparison of the pressure waveforms in this section excludes the data from test 4, which can be found in Appendix A. Reflected pressures on the calibration plate were very consistent among the four 800-psi tests, demonstrating a high degree of repeatability. Figures 18 and 19 show comparisons of the pressure and impulse for all four 800-psi tests from gauges CP3 and CP9, respectively, located on the calibration plate. Pressures along the sidewall of the BLS near the structure were very consistent until approximately 50 ms, after which minor variability can be observed in the histories. Figures 20 and 21 show comparisons of the pressure and impulse for all four 800-psi tests from gauges G1 and G2, respectively, located on the side wall of the BLS. The greater variation observed after approximately 50 ms corresponds to the arrival of the driver gases and associated contact surface at the side wall and structure gauge locations. In the previous set of experiments in this series (Dallriva et al. 2016b), this phenomenon was not observed. In those experiments, the BLS was unvented, and the calibration plate was nearer the location of the structure, resulting in a reflected pressure wave that prevented the driver material from reaching the pressure gauges during the recorded time frame for those experiments. A comparison of representative pressure waveforms recorded on the front of the structure is shown in Figures 22 and 23, on the back of the structure in Figures 24 and 25, and on the right side of the structure in Figures 26 and 27. All of these show excellent repeatability among the replicate experiments until about 45 ms, after which time the effect of the contact surface at the pressure gauge locations manifests in higher experimental variability.

Individual plots showing both pressure and impulse for all of the gauges from Experiments 1 through 5 are shown in Appendix A.

Figure 18. Comparison of pressure records on calibration plate, 0-degree obliquity tests – Gauge CP3.

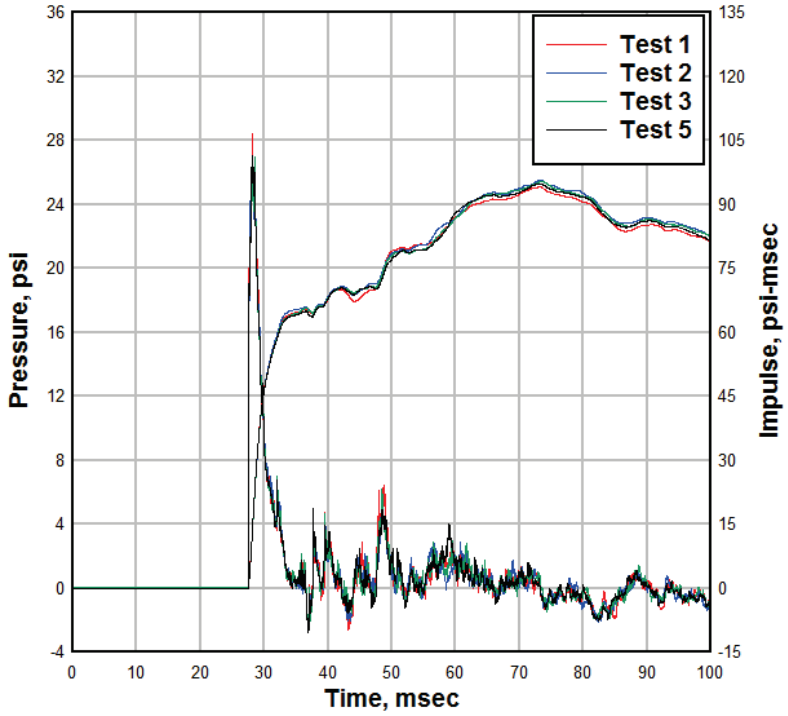


Figure 19. Comparison of pressure records on calibration plate, 0-degree obliquity tests – Gauge CP9.

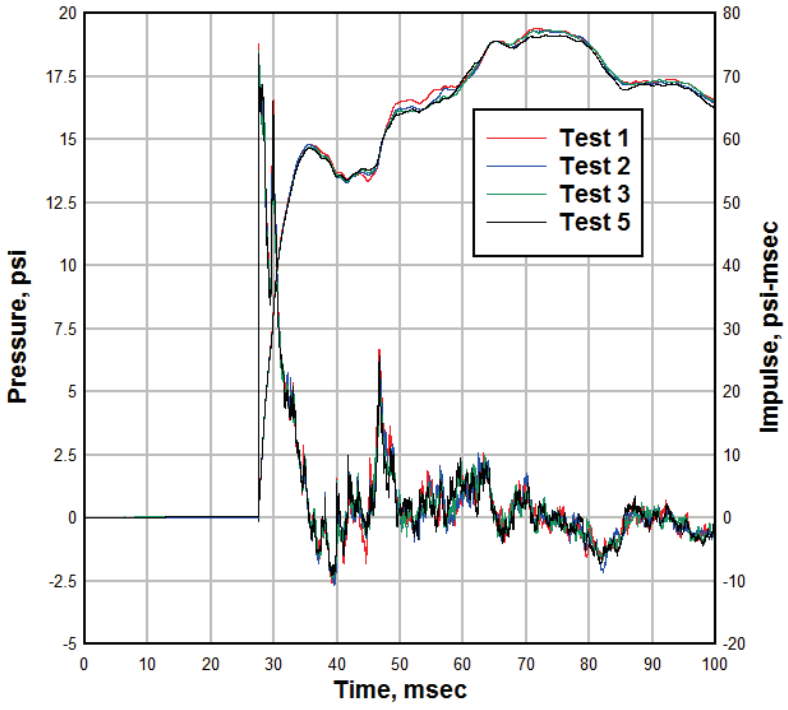


Figure 20. Comparison of pressure records on BLS sidewall, 0-degree obliquity tests – Gauge G1.

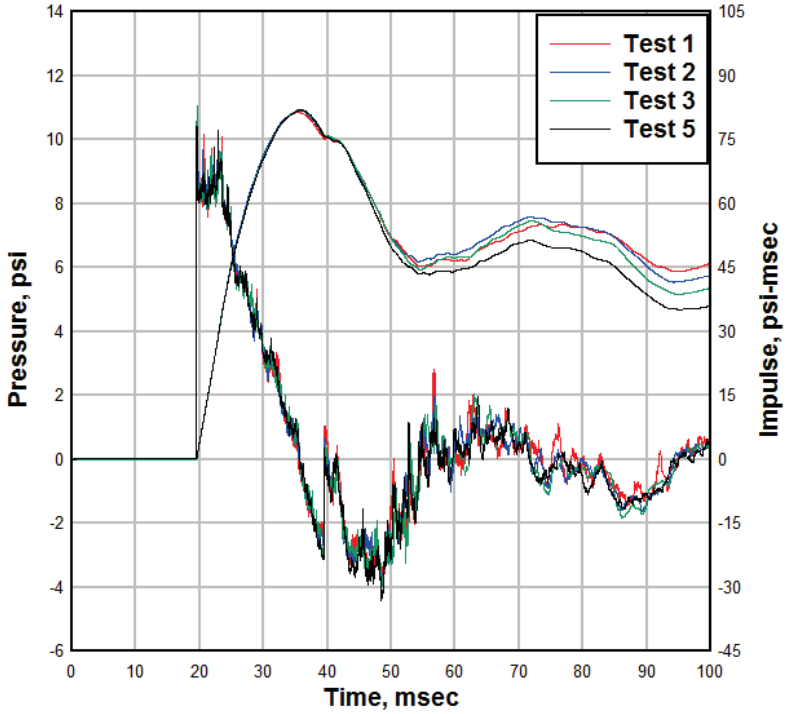


Figure 21. Comparison of pressure records on BLS sidewall, 0-degree obliquity tests – Gauge G2.

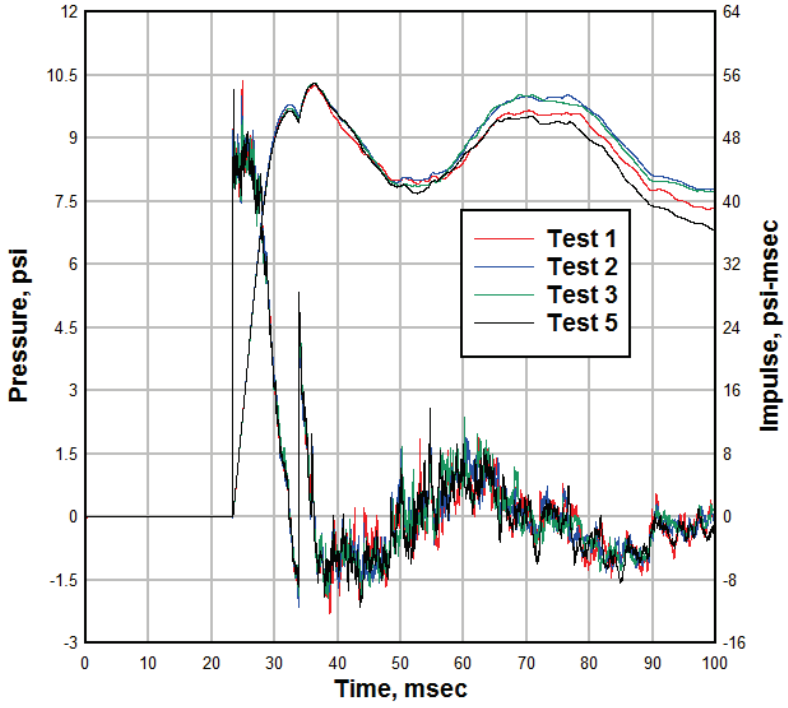


Figure 22. Comparison of pressure records on front of structure, 0-degree obliquity tests – Gauge PBF3.

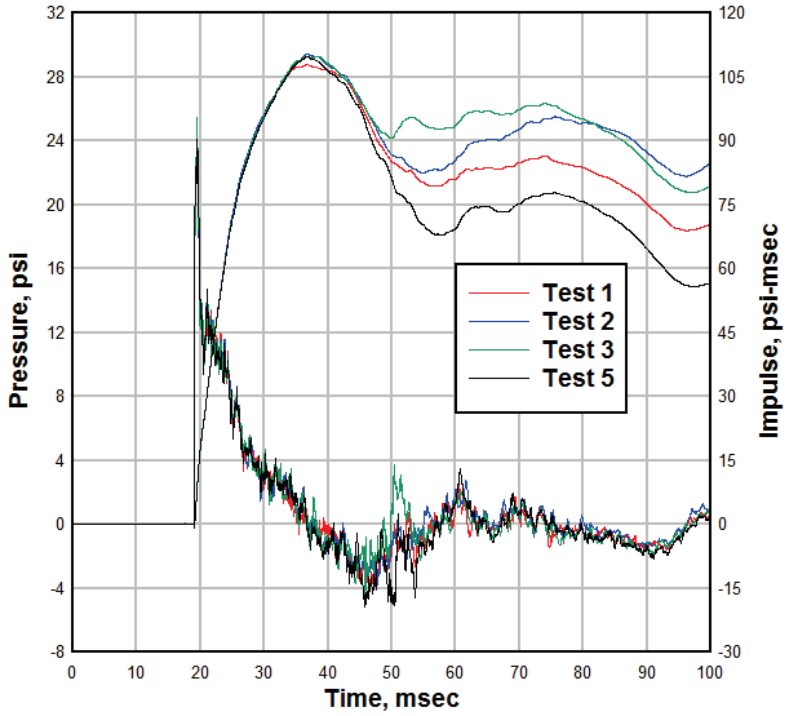


Figure 23. Comparison of pressure records on front of structure, 0-degree obliquity tests – Gauge PBF6.

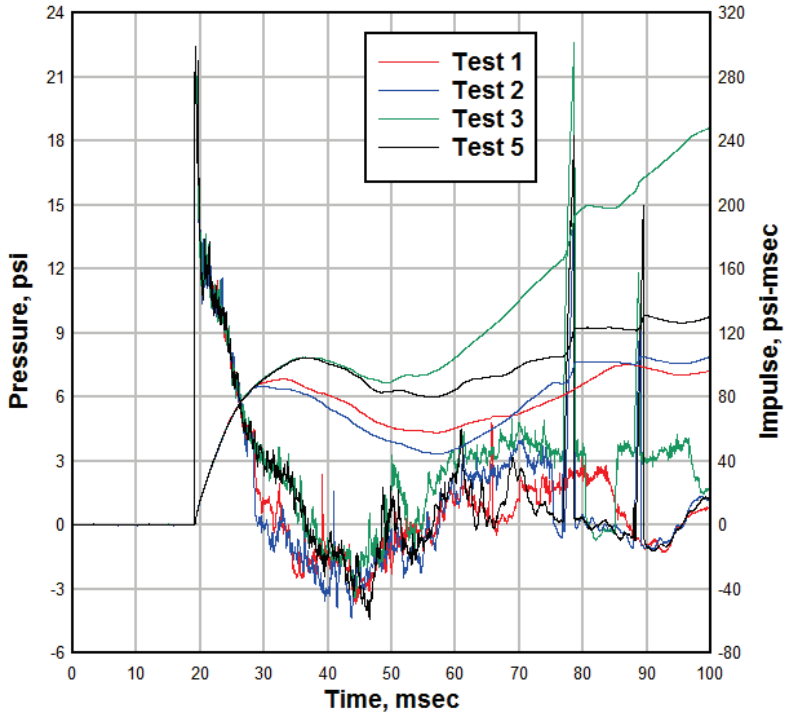


Figure 24. Comparison of pressure records on back of structure, 0-degree obliquity tests – Gauge PBB1.

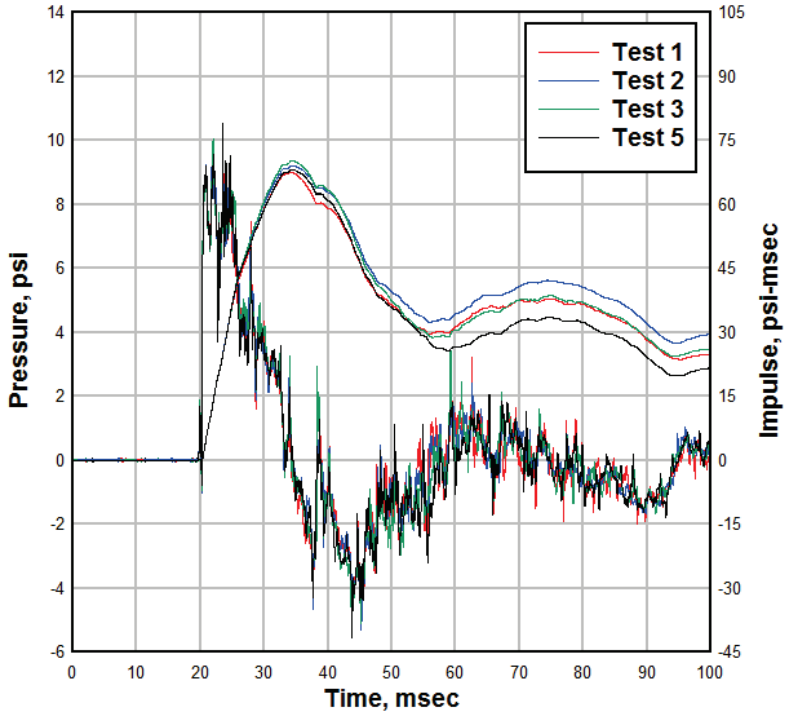


Figure 25. Comparison of pressure records on back of structure, 0-degree obliquity tests – Gauge PBB4.

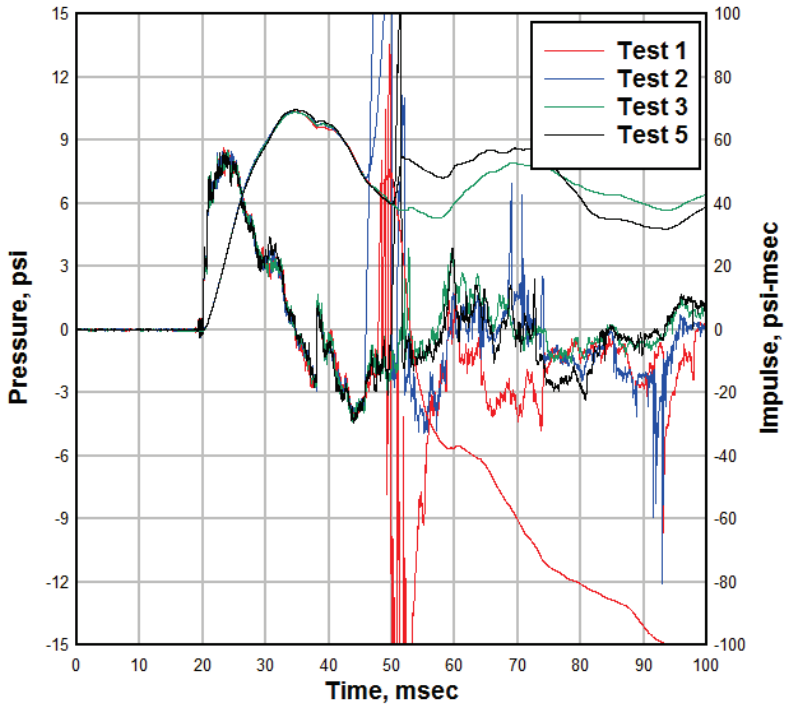


Figure 26. Comparison of pressure records on side of structure, 0-degree obliquity tests – Gauge PBR1.

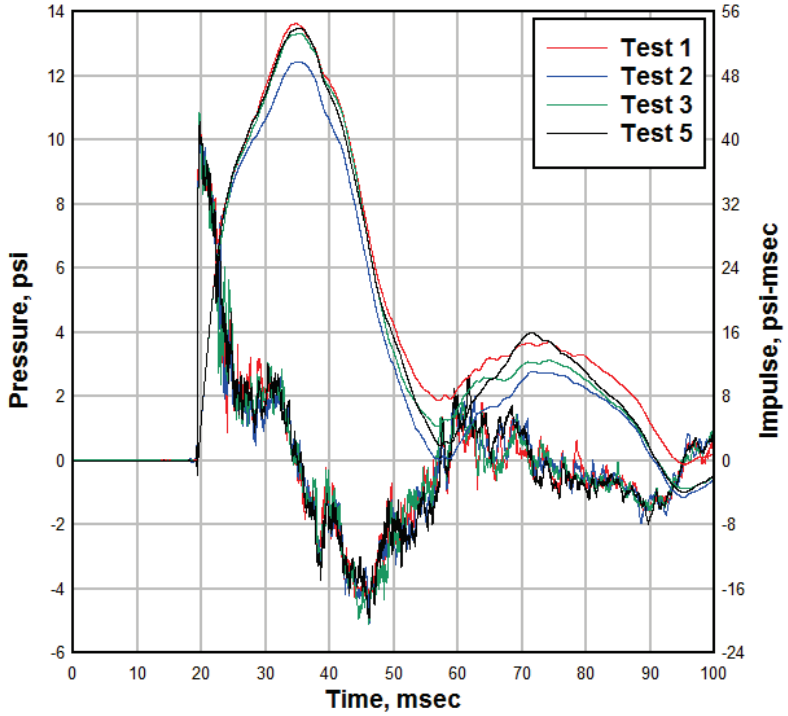
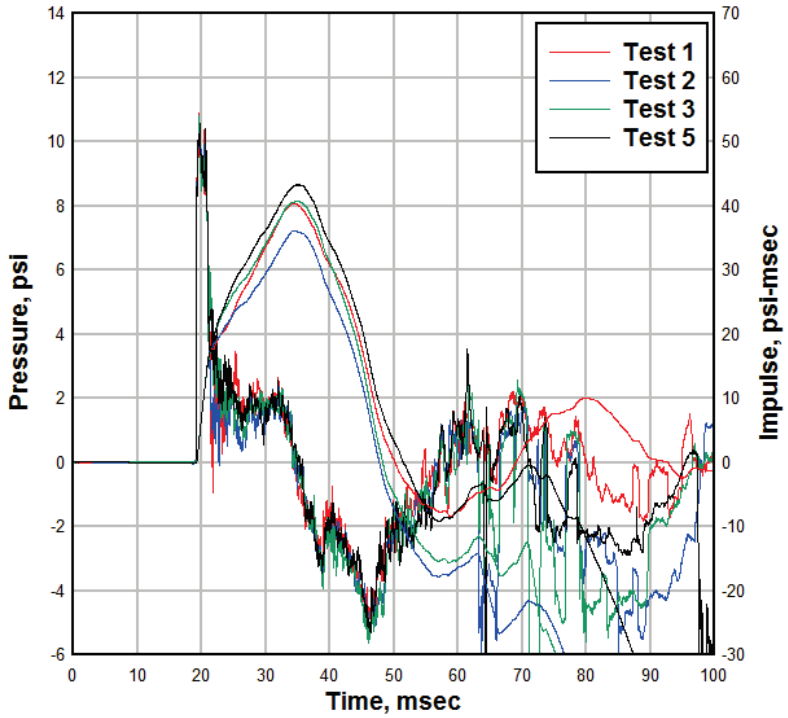


Figure 27. Comparison of pressure records on side of structure, 0-degree obliquity tests – Gauge PBR3.



3.1.2 30-degree obliquity

Five tests were conducted with the structure rotated at 30-degree obliquity. All five tests were performed with a burst pressure of 800 psi. The pressure at the calibration plate and sidewall gauges exhibited similar behavior to the 0-degree obliquity tests with high repeatability. Results for all five tests at the calibration plate gauge location CP9 and BLS wall gauge location G1 are shown in Figures 28 and 29, respectively. Representative waveforms are shown for the front of the structure in Figures 30 and 31, the back of the structure in Figures 32 and 33, and the sides of the structure in Figures 34 and 35. Similar to the 0-degree obliquity tests, the results are very consistent until about 45 ms, after which the arrival of the contact surface at the structure location results in greater experimental variability.

Individual plots showing both pressure and impulse for all of the gauges from Experiments 6 through 10 are shown in Appendix B.

Figure 28. Comparison of pressure records on calibration plate, 30-degree obliquity tests– Gauge CP9.

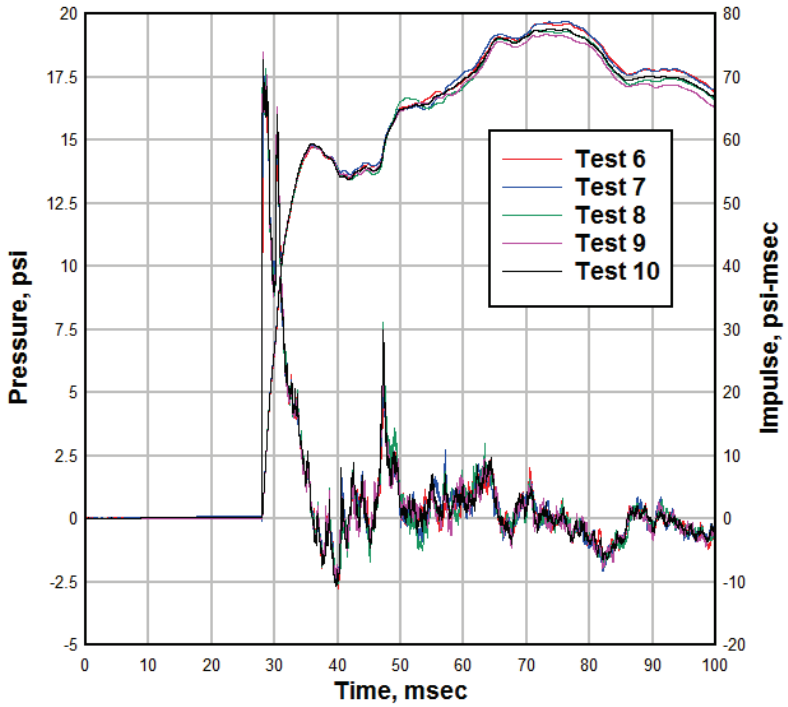


Figure 29. Comparison of pressure records on BLS sidewall, 30-degree obliquity tests – Gauge G1.

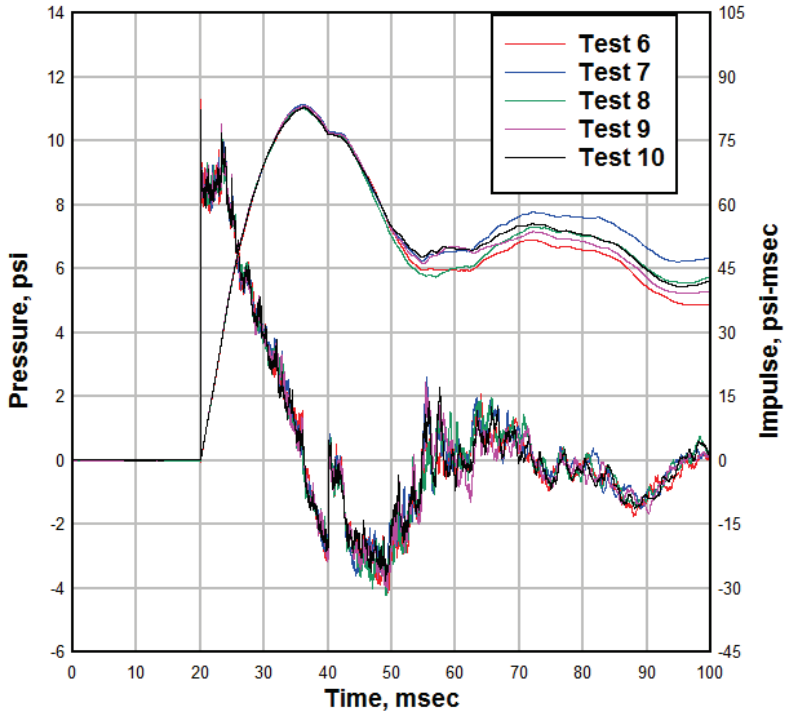


Figure 30. Comparison of pressure records on front of structure, 30-degree obliquity tests – Gauge PBF3.

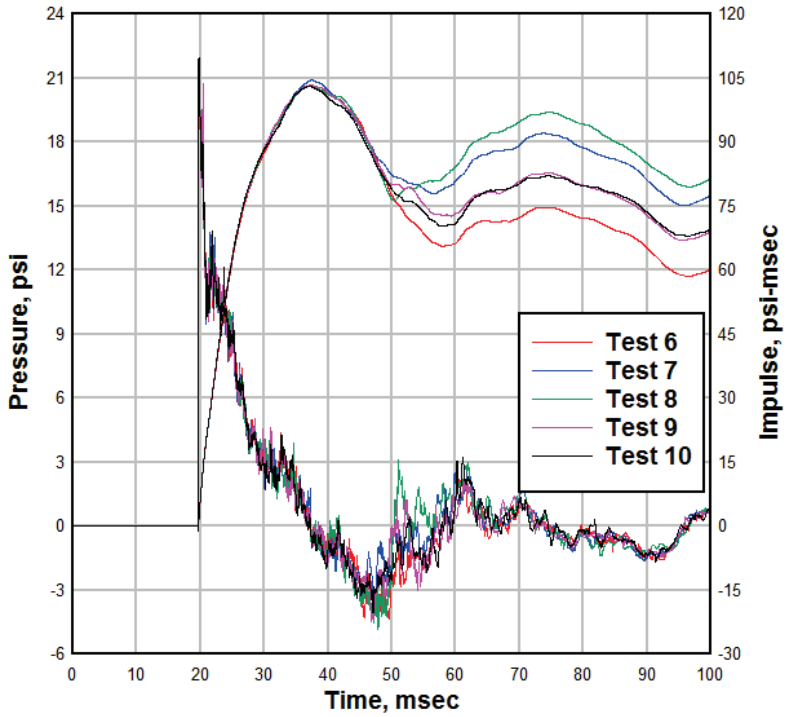


Figure 31. Comparison of pressure records on front of structure, 30-degree obliquity tests – Gauge PBF6.

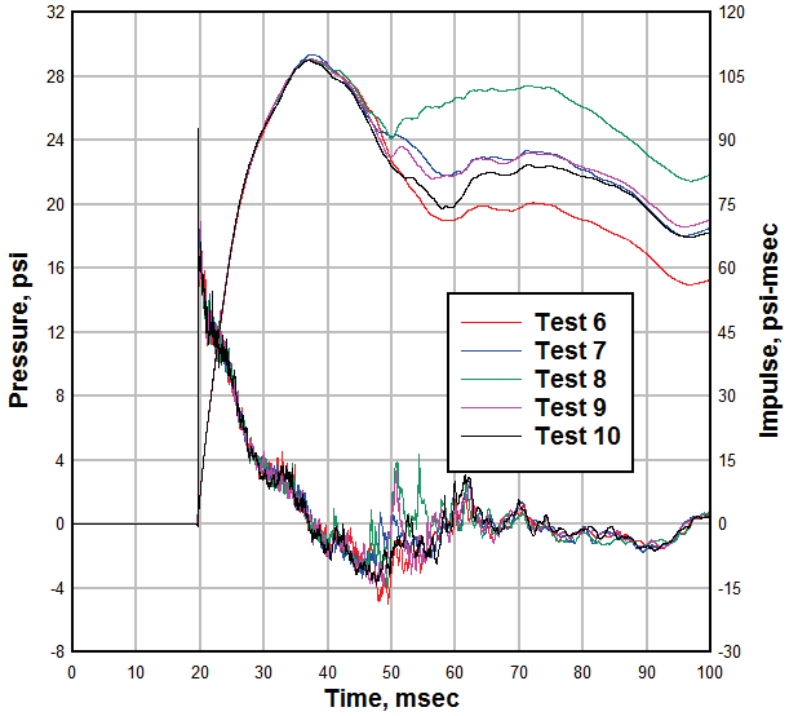


Figure 32. Comparison of pressure records on back of structure, 30- degree obliquity tests – Gauge PBB1.

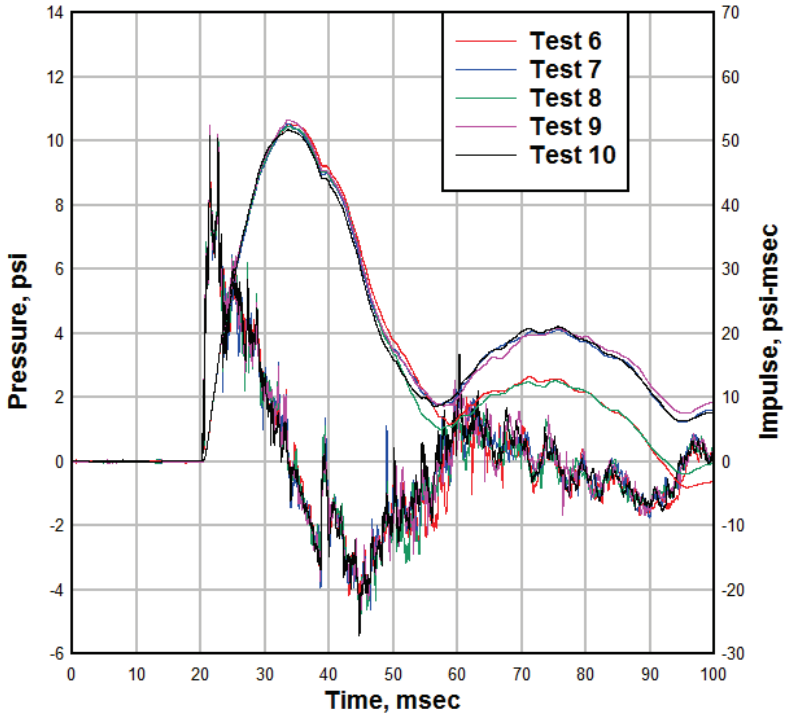


Figure 33. Comparison of pressure records on back of structure, 30-degree obliquity tests – Gauge PBB4.

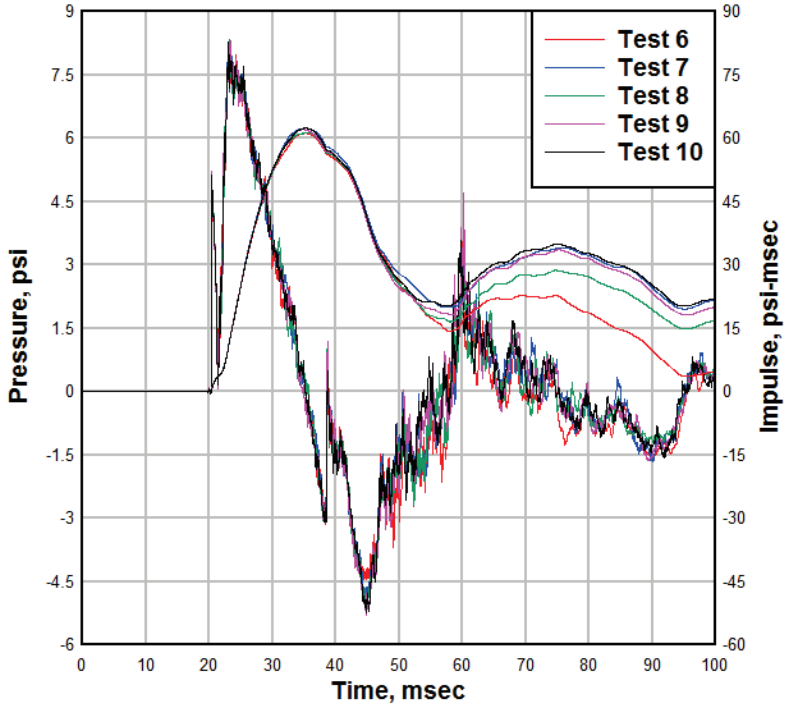


Figure 34. Comparison of pressure records on side of structure, 30-degree obliquity tests – Gauge PBR1.

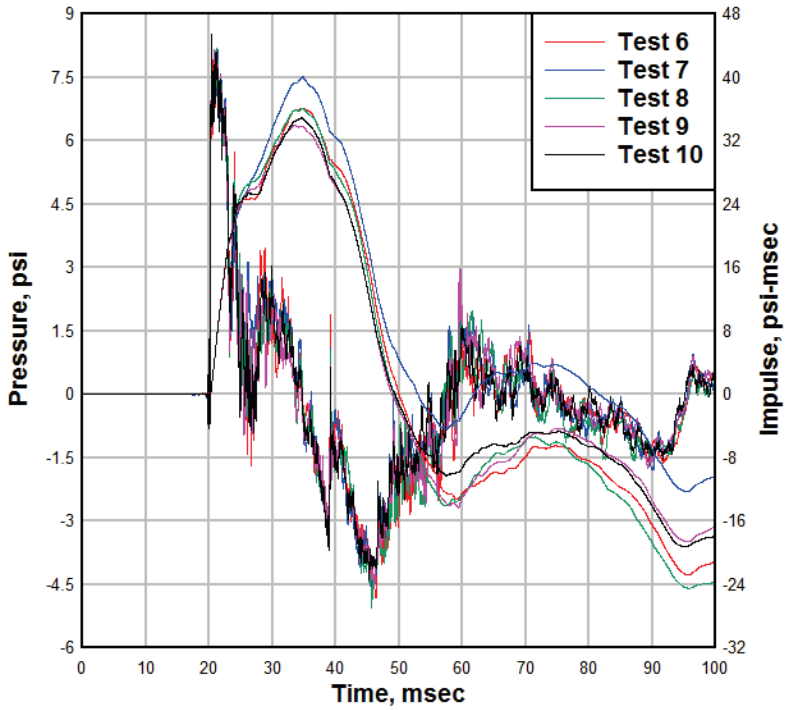
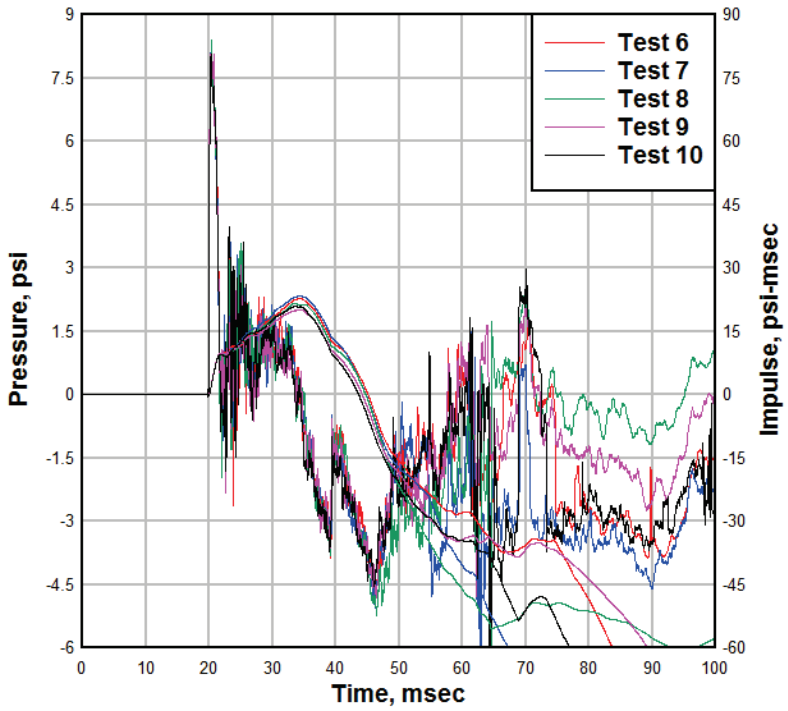


Figure 35. Comparison of pressure records on side of structure, 30-degree obliquity tests – Gauge PBR3.



3.1.3 45-degree obliquity

Six tests were conducted with the structure rotated at 45-degree obliquity. All six tests were performed with a burst pressure of 800 psi. The pressure at the calibration plate and sidewall gauges exhibited behavior similar to the 0- and 30-degree obliquity tests. Results for all six tests at calibration plate gauge location CP9 and BLS wall gauge location G1 are shown in Figures 36 and 37, respectively. Representative waveforms are shown for the front of the structure in Figures 38 and 39, the back of the structure in Figures 40 and 41, and the sides of the structure in Figures 42 and 43. Similar to the 0- and 30-degree obliquity tests, the results are very consistent until about 45 ms, after which the arrival of the contact surface at the structure location results in greater experimental variability.

Individual plots showing both pressure and impulse for all of the gauges from Experiments 11 through 16 are shown in Appendix C.

Figure 36. Comparison of pressure records on calibration plate, 45-degree obliquity tests – Gauge CP9.

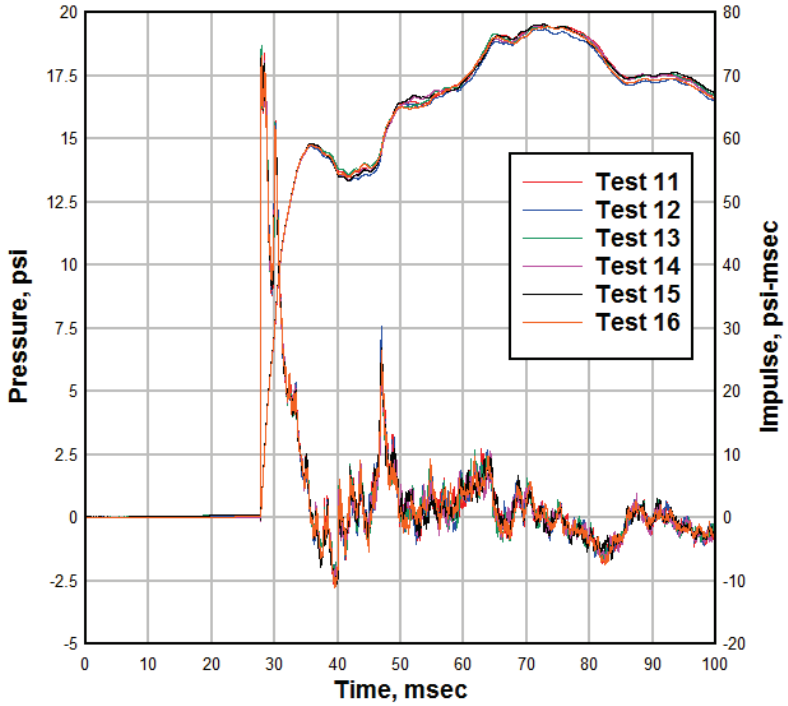


Figure 37. Comparison of pressure records on BLS sidewall, 45-degree obliquity tests – Gauge G1.

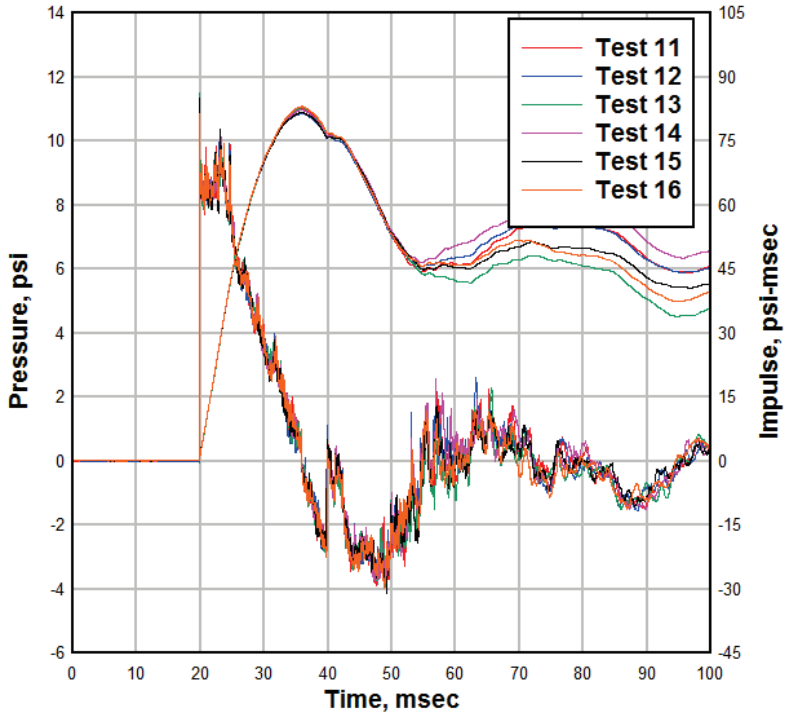


Figure 38. Comparison of pressure records on front of structure, 45-degree obliquity tests – Gauge PBF3.

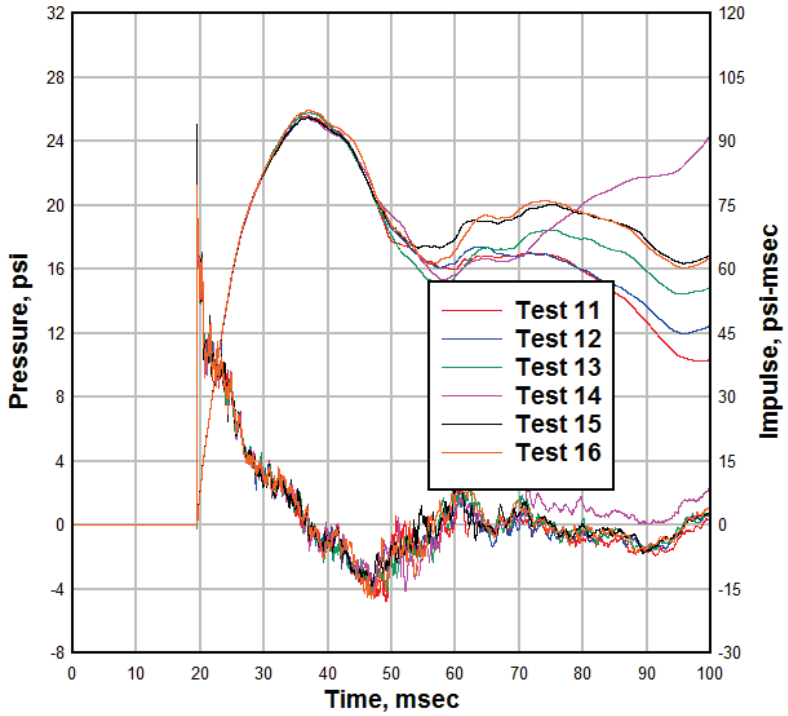


Figure 39. Comparison of pressure records on front of structure, 45-degree obliquity tests – Gauge PBF6.

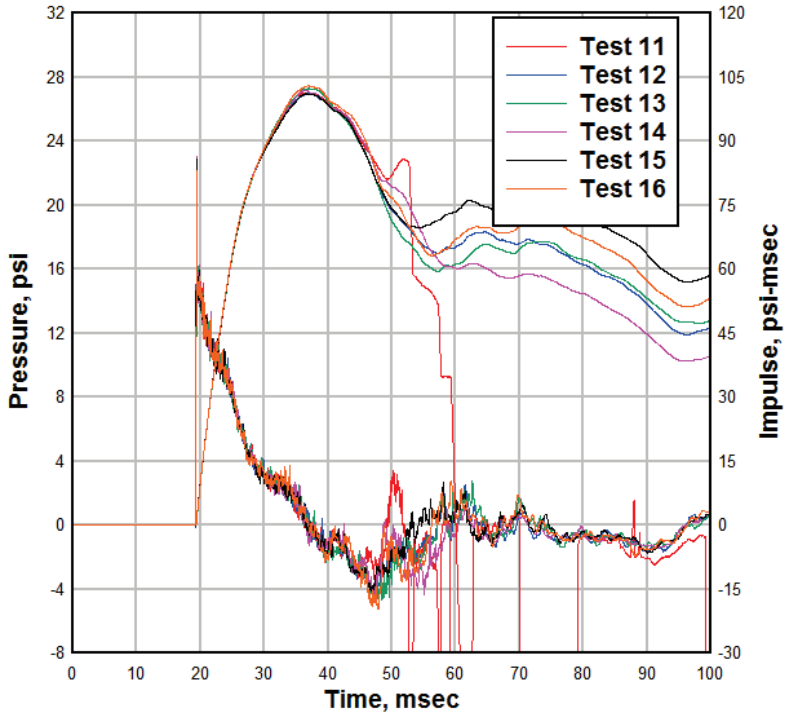


Figure 40. Comparison of pressure records on back of structure, 45-degree obliquity tests – Gauge PBB1.

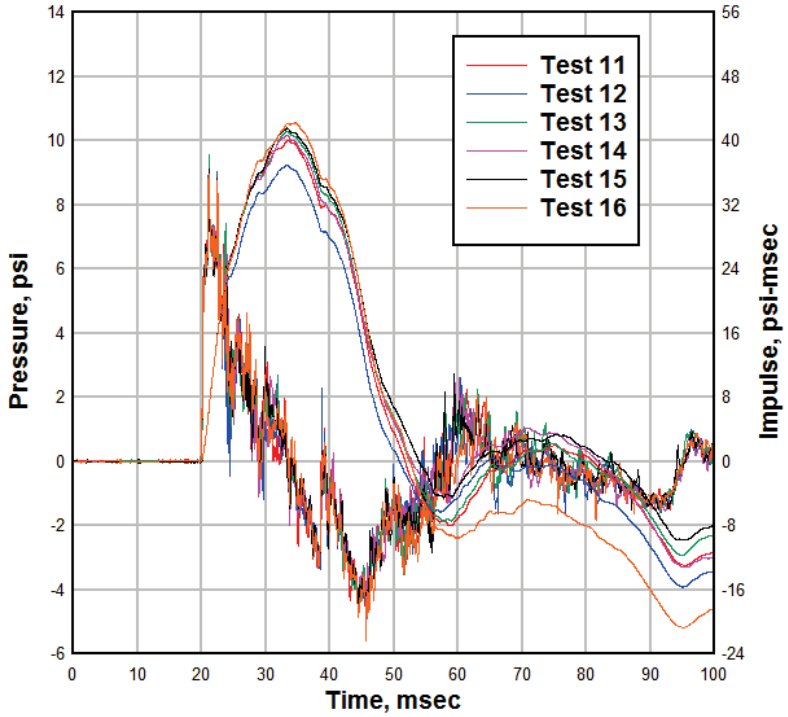


Figure 41. Comparison of pressure records on back of structure, 45-degree obliquity tests – Gauge PBB4.

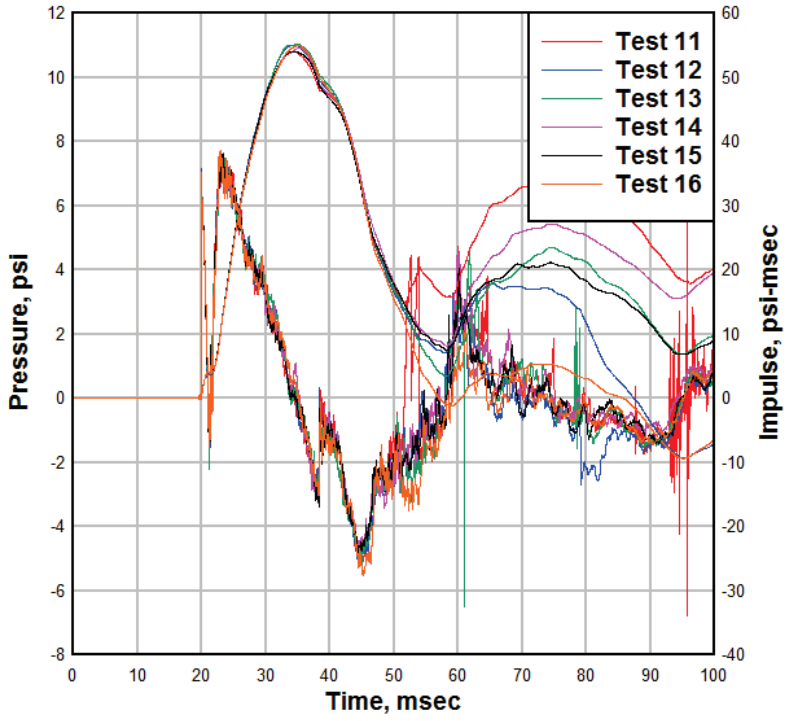


Figure 42. Comparison of pressure records on side of structure, 45-degree obliquity tests – Gauge PBR1.

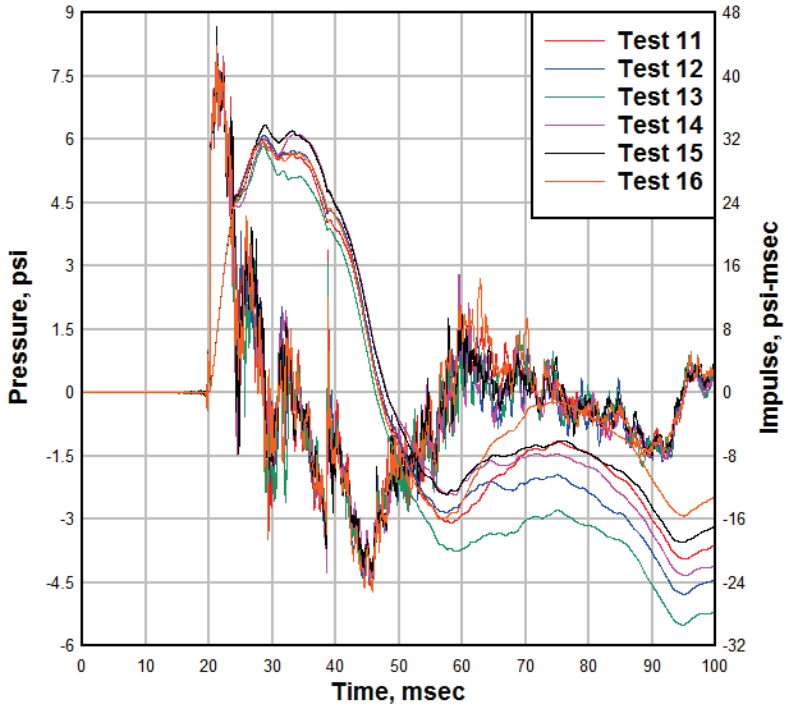
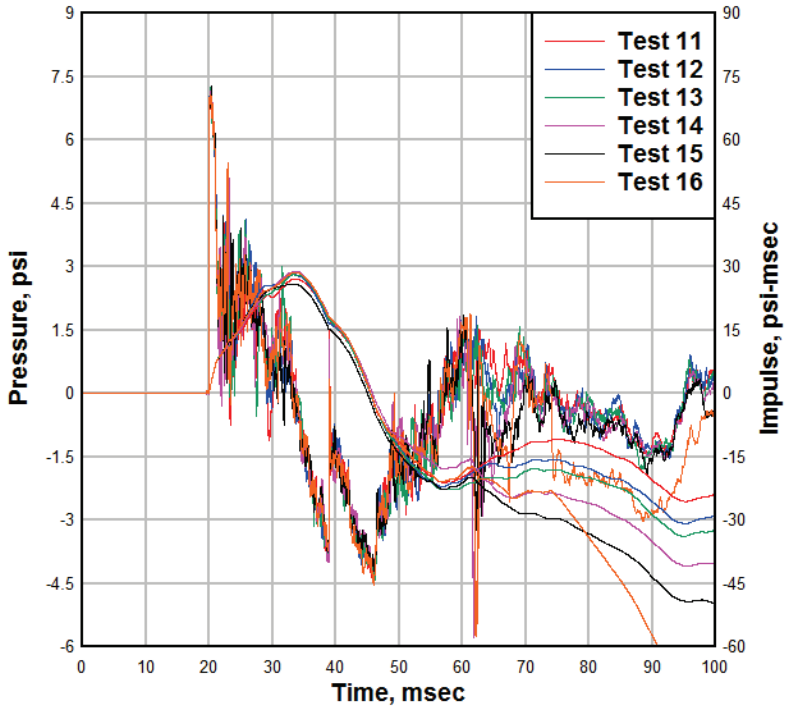


Figure 43. Comparison of pressure records on side of structure, 45-degree obliquity tests – Gauge PBR3.



3.2 Experiment uncertainty

The uncertainty in the experimental values of pressure and impulse was evaluated for each set of replicate experiments for which, as closely as possible, the identical BLS setup was used from test to test. The analysis assumes that the data values constitute a sample population drawn from an underlying Gaussian parent population. Ninety-five percent confidence intervals were computed to provide the range within which one should expect the next data value to lie if an additional test was to be conducted.

The 95% confidence interval for a sample of N measurements of X drawn from a Gaussian distribution was based on the precision index, P, defined by the equation

$$P_X = tS_X$$

and the estimated 95% confidence interval is defined by

$$\bar{X} \pm P_X$$

where

$\bar{X}$ = the sample mean of X
S_x = the sample standard deviation
t = the value from the t distribution with N-1 degrees of freedom corresponding to the 95% confidence limit

For each set of replicate experiments, the peak pressure and peak impulse associated with the positive phase of the simulated blast wave were compared. The initial peak pressure and peak impulse are both evaluated between 0 and 45 ms to exclude the effect of the contact surface on the measurement. For gauge locations where a clearly defined initial peak is not present, Figure 24 for example, or where a small initial peak is immediately followed by a larger sharply defined peak, Figure 33 for example, the peak pressure is simply defined as the maximum value occurring between 0 and 45 ms.

Figures 44 and 45 present the mean values and 95% confidence intervals computed for the initial peak pressure and initial peak impulse, respectively, for the four 0-degree obliquity tests conducted at 800 psi burst pressure. The data can be found in tabular form in Table 1 .

As indicated by the confidence intervals in Figures 44 and 45 and the waveform comparisons presented in Section 3.1, the data exhibited a very reasonable degree of repeatability among the four experiments prior to the arrival of the contact surface at about 45 ms, with the exception of the peak impulse on PBF6. The pressure traces for PBF6 were very repeatable up until about 28 ms, after which point variation in the rate of pressure decay was observed resulting in the observed variation in peak impulse.

In Figure 44, gauge CP3 is observed to record a significantly higher peak pressure than the other gauges on the calibration plate. A significantly higher peak impulse for this gauge is also shown in Figure 45. This behavior was also observed for the 30- and 45-degree obliquity experiments and is anomalous for a planar shockwave when comparing gauges on the calibration plate at a similar distance from the center line of the BLS in locations that are unshielded by the structure such as CP5 (see Figures 5 and 11). To evaluate whether this behavior was a real response or an artifact of the sensor that was used, during the next set of experiments conducted under this effort, which will be reported in Report 4 of this series, the pressure gauge at the CP3 location was replaced. The pressures and impulses recorded at location CP3 after replacing the sensor were of comparable magnitude to the remaining gauges on the calibration plate indicating the anomalous response observed for CP3 during this series of experiments was a sensor artifact. Although anomalous, the results for CP3 are included here to demonstrate the need for multiple gauge locations per face during the experimental phase of the study. If only one pressure measurement was obtained across the calibration plate, the anomalous results for CP3 would not have been identified. It also emphasizes that the individual experimental data must be closely examined for any verification and validation effort.

Figure 44. 95% confidence intervals on measured peak pressure for 0-degree obliquity.

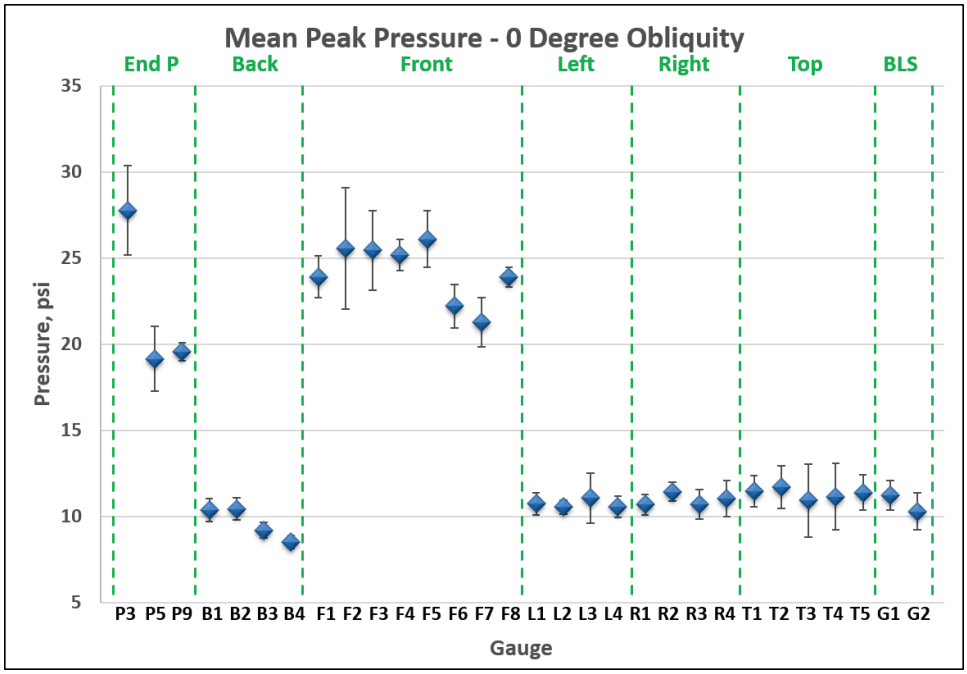


Figure 45. 95% confidence intervals on measured peak impulse for 0-degree obliquity.

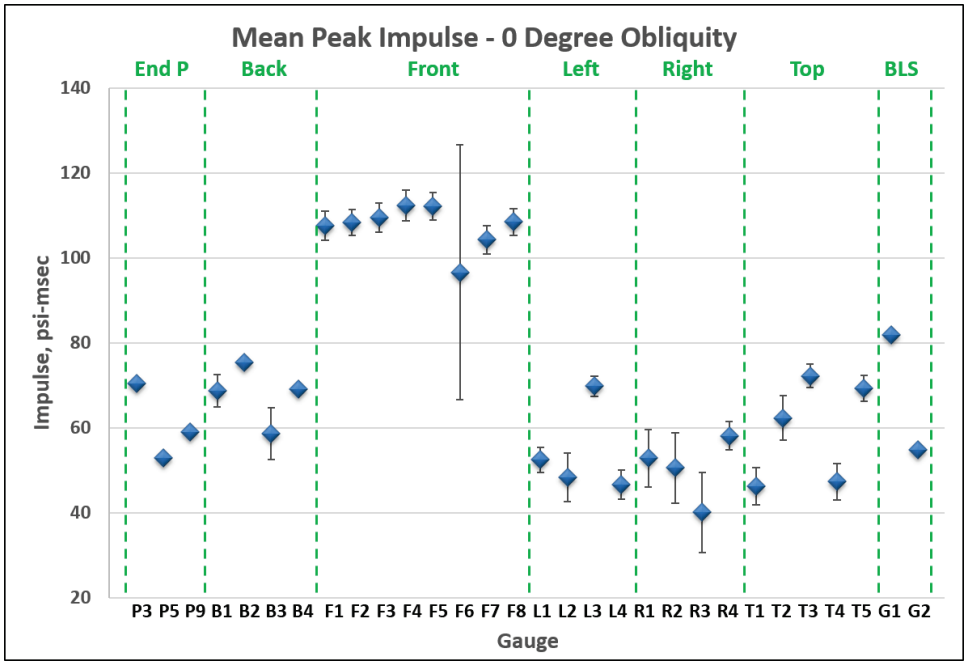


Table 1. Data confidence intervals – 0-degree obliquity.

Gauge	95% Confidence on P	95% Confidence on P_{mean}	95% Confidence on I	95% Confidence on I_{mean}
CP3	27.8 +/- 2.6	27.8 +/- 1.3	70 +/- 1	70 +/- 0
CP5	19.1 +/- 1.9	19.1 +/- 0.9	53 +/- 1	53 +/- 0
CP9	19.6 +/- 0.5	19.6 +/- 0.3	59 +/- 1	59 +/- 1
PBB1	10.4 +/- 0.7	10.4 +/- 0.3	69 +/- 4	69 +/- 2
PBB2	10.4 +/- 0.7	10.4 +/- 0.3	75 +/- 1	75 +/- 1
PBB3	9.2 +/- 0.4	9.2 +/- 0.2	59 +/- 6	59 +/- 3
PBB4	8.5 +/- 0.4	8.5 +/- 0.2	69 +/- 1	69 +/- 1
PBF1	23.9 +/- 1.2	23.9 +/- 0.6	108 +/- 3	108 +/- 2
PBF2	25.6 +/- 3.5	25.6 +/- 1.8	108 +/- 3	108 +/- 2
PBF3	25.4 +/- 2.3	25.4 +/- 1.2	109 +/- 3	109 +/- 2
PBF4	25.2 +/- 0.9	25.2 +/- 0.5	112 +/- 4	112 +/- 2
PBF5	26.1 +/- 1.6	26.1 +/- 0.8	112 +/- 3	112 +/- 2
PBF6	22.2 +/- 1.3	22.2 +/- 0.6	97 +/- 30	97 +/- 15
PBF7	21.3 +/- 1.4	21.3 +/- 0.7	104 +/- 3	104 +/- 2
PBF8	23.9 +/- 0.6	23.9 +/- 0.3	108 +/- 3	108 +/- 2
PBL1	10.7 +/- 0.7	10.7 +/- 0.3	52 +/- 3	52 +/- 1
PBL2	10.5 +/- 0.4	10.5 +/- 0.2	48 +/- 6	48 +/- 3
PBL3	11.1 +/- 1.5	11.1 +/- 0.7	70 +/- 2	70 +/- 1
PBL4	10.5 +/- 0.6	10.5 +/- 0.3	47 +/- 3	47 +/- 2
PBR1	10.7 +/- 0.6	10.7 +/- 0.3	53 +/- 7	53 +/- 3
PBR2	11.4 +/- 0.6	11.4 +/- 0.3	51 +/- 8	51 +/- 4
PBR3	10.7 +/- 0.8	10.7 +/- 0.4	40 +/- 9	40 +/- 5
PBR4	11.0 +/- 1.1	11.0 +/- 0.5	58 +/- 3	58 +/- 2
PBT1	11.5 +/- 0.9	11.5 +/- 0.5	46 +/- 4	46 +/- 2
PBT2	11.7 +/- 1.2	11.7 +/- 0.6	62 +/- 5	62 +/- 3
PBT3	10.9 +/- 2.1	10.9 +/- 1.1	72 +/- 3	72 +/- 1
PBT4	11.1 +/- 1.9	11.1 +/- 1.0	47 +/- 4	47 +/- 2
PBT5	11.4 +/- 1.0	11.4 +/- 0.5	69 +/- 3	69 +/- 2
G1	11.2 +/- 0.9	11.2 +/- 0.4	82 +/- 1	82 +/- 0
G2	10.3 +/- 1.1	10.3 +/- 0.5	55 +/- 1	55 +/- 0

Figures 46 and 47 present the mean values and 95% confidence interval for the initial peak pressures and initial peak impulses, respectively, for the five 30-degree obliquity tests. The data are in tabular form in Table 2. Gauge PBL4 over-ranged during this series of experiments and was therefore removed from the comparisons presented in Figures 46 and 47. As indicated by the confidence intervals and the waveform comparisons presented in Section 3.1, the data for the remaining gauges exhibited a

very reasonable degree of repeatability among the five experiments prior to the arrival of the contact surface at about 45 ms.

Figure 46. 95% confidence intervals on measured peak pressure for 30-degree obliquity.

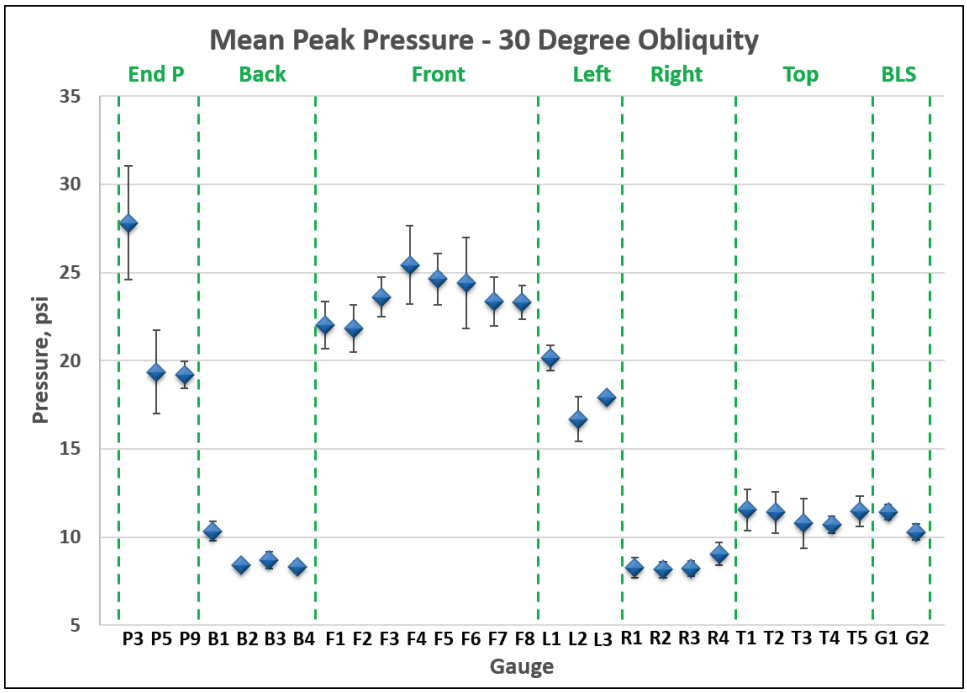


Figure 47. 95% confidence intervals on measured peak impulse for 30-degree obliquity.

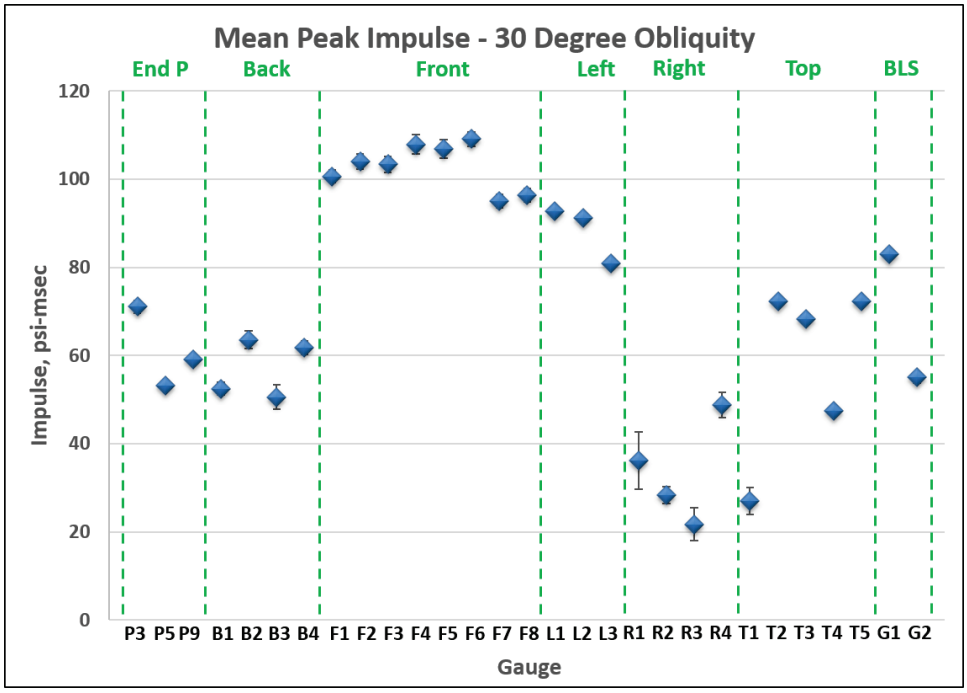


Table 2. Data confidence intervals – 30-degree obliquity.

Gauge	95% Confidence on P	95% Confidence on P_{mean}	95% Confidence on I	95% Confidence on I_{mean}
CP3	27.8 +/- 3.2	27.8 +/- 1.4	71 +/- 1	71 +/- 1
CP5	19.4 +/- 2.4	19.4 +/- 1.1	53 +/- 1	53 +/- 0
CP9	19.2 +/- 0.8	19.2 +/- 0.3	59 +/- 1	59 +/- 0
PBB1	10.3 +/- 0.6	10.3 +/- 0.2	53 +/- 2	53 +/- 1
PBB2	8.4 +/- 0.2	8.4 +/- 0.1	64 +/- 2	64 +/- 1
PBB3	8.7 +/- 0.5	8.7 +/- 0.2	51 +/- 3	51 +/- 1
PBB4	8.3 +/- 0.3	8.3 +/- 0.1	62 +/- 2	62 +/- 1
PBF1	22.0 +/- 1.3	22.0 +/- 0.6	101 +/- 1	101 +/- 1
PBF2	21.8 +/- 1.3	21.8 +/- 0.6	104 +/- 2	104 +/- 1
PBF3	23.6 +/- 1.1	23.6 +/- 0.5	103 +/- 2	103 +/- 1
PBF4	25.4 +/- 2.2	25.4 +/- 1.0	108 +/- 2	108 +/- 1
PBF5	24.6 +/- 1.4	24.6 +/- 0.6	107 +/- 2	107 +/- 1
PBF6	24.4 +/- 2.6	24.4 +/- 1.2	109 +/- 2	109 +/- 1
PBF7	23.4 +/- 1.4	23.4 +/- 0.6	95 +/- 2	95 +/- 1
PBF8	23.3 +/- 1.0	23.3 +/- 0.4	96 +/- 2	96 +/- 1
PBL1	20.2 +/- 0.7	20.2 +/- 0.3	93 +/- 1	93 +/- 0
PBL2	16.7 +/- 1.3	16.7 +/- 0.6	91 +/- 1	91 +/- 0
PBL3	17.9 +/- 0.3	17.9 +/- 0.1	81 +/- 1	81 +/- 0
PBL4	13.0 +/- 0.5	13.0 +/- 0.2	93 +/- 2	93 +/- 1
PBR1	8.3 +/- 0.6	8.3 +/- 0.3	36 +/- 6	36 +/- 3
PBR2	8.1 +/- 0.4	8.1 +/- 0.2	28 +/- 2	28 +/- 1
PBR3	8.2 +/- 0.4	8.2 +/- 0.2	22 +/- 4	22 +/- 2
PBR4	9.0 +/- 0.6	9.0 +/- 0.3	49 +/- 3	49 +/- 1
PBT1	11.5 +/- 1.2	11.5 +/- 0.5	27 +/- 3	27 +/- 1
PBT2	11.4 +/- 1.2	11.4 +/- 0.5	72 +/- 1	72 +/- 0
PBT3	10.8 +/- 1.4	10.8 +/- 0.6	68 +/- 1	68 +/- 0
PBT4	10.7 +/- 0.5	10.7 +/- 0.2	47 +/- 1	47 +/- 0
PBT5	11.5 +/- 0.8	11.5 +/- 0.4	72 +/- 1	72 +/- 0
G1	11.4 +/- 0.4	11.4 +/- 0.2	83 +/- 1	83 +/- 0
G2	10.3 +/- 0.5	10.3 +/- 0.2	55 +/- 1	55 +/- 1

Figures 48 and 49 present the mean values and 95% confidence interval for the initial peak pressures and initial peak impulses, respectively, for the six 45-degree obliquity tests. The data can be also found in Table 3. Gauge PBL4 again over-ranged in this series of experiments and was excluded from the uncertainty analysis presented in Figures 48 and 49. As indicated by the confidence intervals and the waveform comparisons

presented in Section 3.1, the data for the remaining gauges exhibited a very reasonable degree of repeatability among the six experiments prior to the arrival of the contact surface around 45 ms.

Figure 48. 95% confidence intervals on measured peak pressure for 45-degree obliquity.

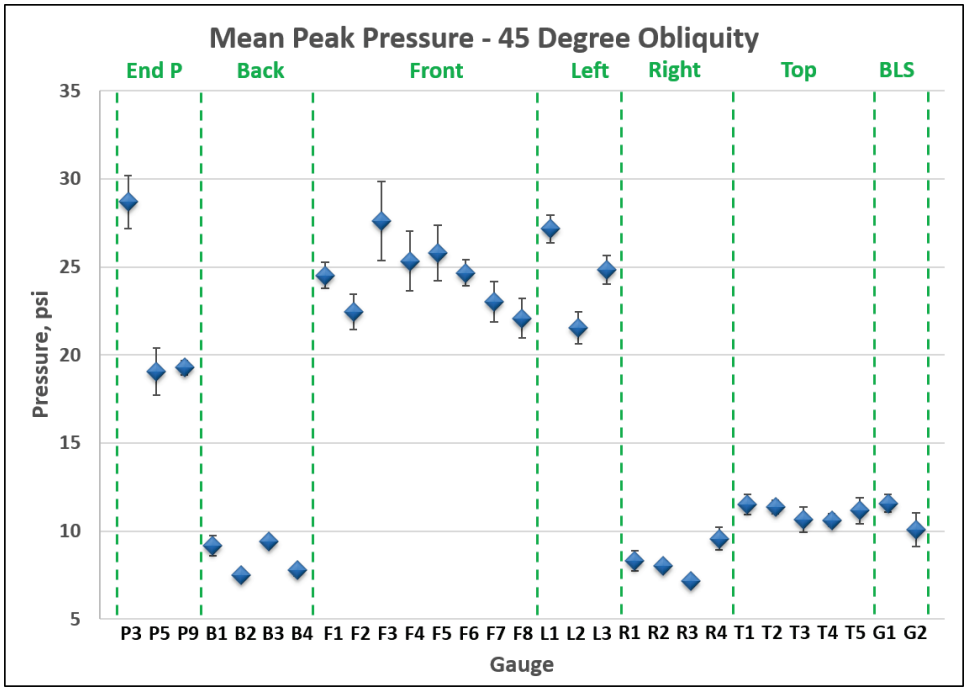


Figure 49. 95% confidence intervals on measured peak impulse 45-degree obliquity.

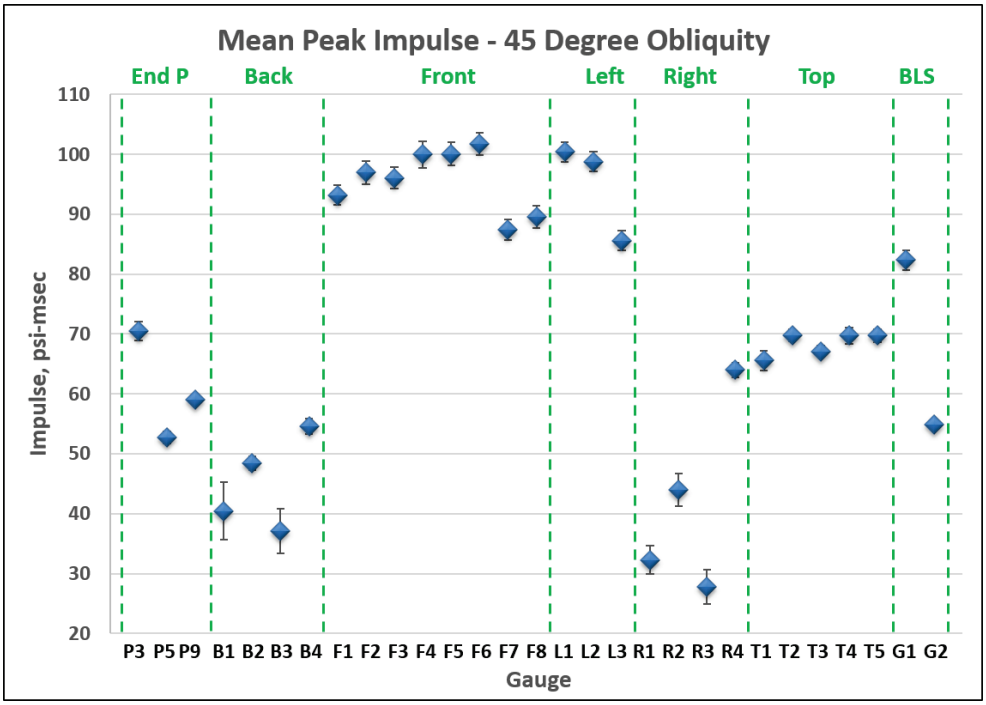


Table 3. Data confidence intervals – 45-degree obliquity.

Gauge	95% Confidence on P	95% Confidence on P_{mean}	95% Confidence on I	95% Confidence on I_{mean}
CP3	28.7 +/- 1.5	28.7 +/- 0.6	71 +/- 2	71 +/- 1
CP5	19.1 +/- 1.3	19.1 +/- 0.5	53 +/- 1	53 +/- 0
CP9	19.3 +/- 0.4	19.3 +/- 0.2	59 +/- 0	59 +/- 0
PBB1	9.2 +/- 0.6	9.2 +/- 0.2	40 +/- 5	40 +/- 2
PBB2	7.5 +/- 0.2	7.5 +/- 0.1	48 +/- 1	48 +/- 0
PBB3	9.4 +/- 0.2	9.4 +/- 0.1	37 +/- 4	37 +/- 2
PBB4	7.8 +/- 0.3	7.8 +/- 0.1	55 +/- 1	55 +/- 1
PBF1	24.5 +/- 0.7	24.5 +/- 0.3	93 +/- 2	93 +/- 1
PBF2	22.5 +/- 1.0	22.5 +/- 0.4	97 +/- 2	97 +/- 1
PBF3	27.6 +/- 2.2	27.6 +/- 0.9	96 +/- 2	96 +/- 1
PBF4	25.3 +/- 1.7	25.3 +/- 0.7	100 +/- 2	100 +/- 1
PBF5	25.8 +/- 1.6	25.8 +/- 0.6	100 +/- 2	100 +/- 1
PBF6	24.7 +/- 0.7	24.7 +/- 0.3	102 +/- 2	102 +/- 1
PBF7	23.0 +/- 1.2	23.0 +/- 0.5	87 +/- 2	87 +/- 1
PBF8	22.1 +/- 1.1	22.1 +/- 0.5	90 +/- 2	90 +/- 1
PBL1	27.2 +/- 0.8	27.2 +/- 0.3	100 +/- 2	100 +/- 1
PBL2	21.6 +/- 0.9	21.6 +/- 0.4	99 +/- 2	99 +/- 1
PBL3	24.8 +/- 0.8	24.8 +/- 0.3	86 +/- 2	86 +/- 1
PBL4	13.2 +/- 0.0	13.2 +/- 0.0	102 +/- 2	102 +/- 1
PBR1	8.3 +/- 0.6	8.3 +/- 0.2	32 +/- 2	32 +/- 1
PBR2	8.0 +/- 0.3	8.0 +/- 0.1	44 +/- 3	44 +/- 1
PBR3	7.2 +/- 0.2	7.2 +/- 0.1	28 +/- 3	28 +/- 1
PBR4	9.6 +/- 0.6	9.6 +/- 0.3	64 +/- 1	64 +/- 0
PBT1	11.5 +/- 0.6	11.5 +/- 0.2	66 +/- 2	66 +/- 1
PBT2	11.4 +/- 0.4	11.4 +/- 0.2	70 +/- 1	70 +/- 0
PBT3	10.7 +/- 0.7	10.7 +/- 0.3	67 +/- 1	67 +/- 0
PBT4	10.6 +/- 0.4	10.6 +/- 0.1	70 +/- 1	70 +/- 1
PBT5	11.2 +/- 0.7	11.2 +/- 0.3	70 +/- 1	70 +/- 0
G1	11.6 +/- 0.5	11.6 +/- 0.2	82 +/- 2	82 +/- 1
G2	10.1 +/- 1.0	10.1 +/- 0.4	55 +/- 0	55 +/- 0

4 Conclusions and Recommendations

Replicate experiments conducted in the BLS produced very repeatable pressure data on the surfaces of the box structure, the walls of the BLS, and the calibration plate. All except two of the 90 peak pressure records produced 95% confidence intervals that were within +/- 15% of the mean. Furthermore, 78 of the 90 peak pressure records measured 95% confidence interval that were within +/- 10% of the mean. All except for two of the 90 measured peak impulse records produced 95% confidence intervals that were within +/- 20% of the mean. Furthermore, 85 of the 90 measured peak impulse records produced 95% confidence intervals were within +/- 15% of the mean, and 78 of the 90 peak impulse records produced 95% confidence intervals that were within +/- 10% of the mean. Visual evaluation of overlaid waveforms for all five (or six) experiments at individual gauge locations showed excellent experiment repeatability. The pressure and impulse waveforms from the experiments combined with uncertainty information in the form of confidence intervals for peak pressure and impulse result in a data set that can be used to evaluate the accuracy of computational models.

The addition of the 4-ft gap between the end of the 8x8 BLS test section and the steel calibration plate significantly reduced the magnitude of the pressure that reflects off of the calibration plate and back onto the box structure. It further provided more time for the initial pressure to engulf the structure and decay prior to the reflection from the calibration plate impinging on the structure from behind. This produced pressure waveforms closer to the open air class of problems that DTRA is interested in compared to the closed configuration of the BLS.

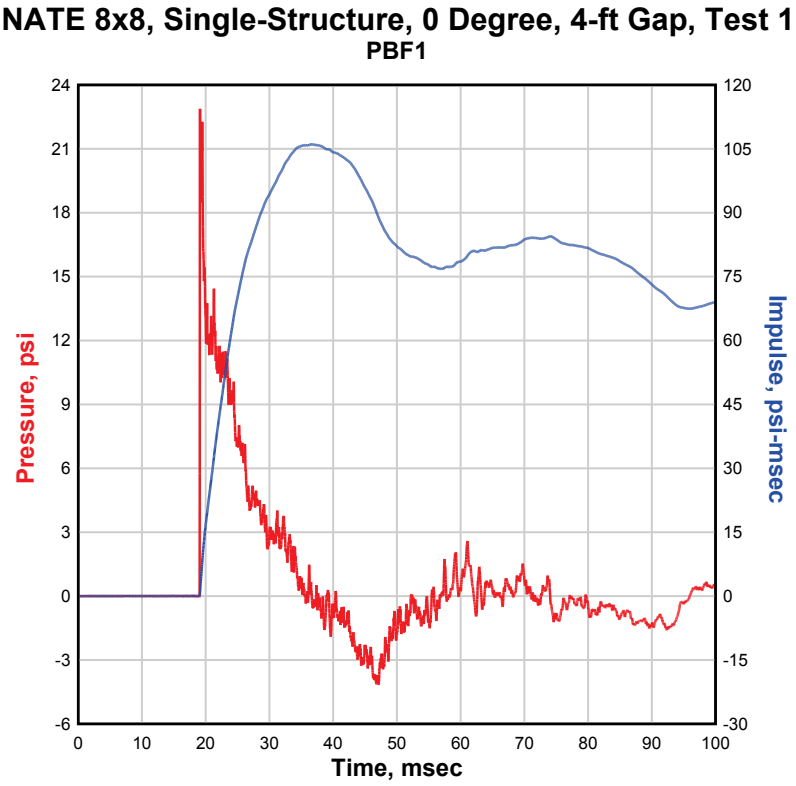
Future testing will be conducted with a two-structure configuration placed inside the BLS. The two structures will be identical, with one structure placed directly behind the other at varying distances to evaluate the effect of shielding on the pressures experienced by the second structure. The 4-ft gap between the end of the 8x8 BLS test section and the steel calibration plate will be maintained for these experiments.

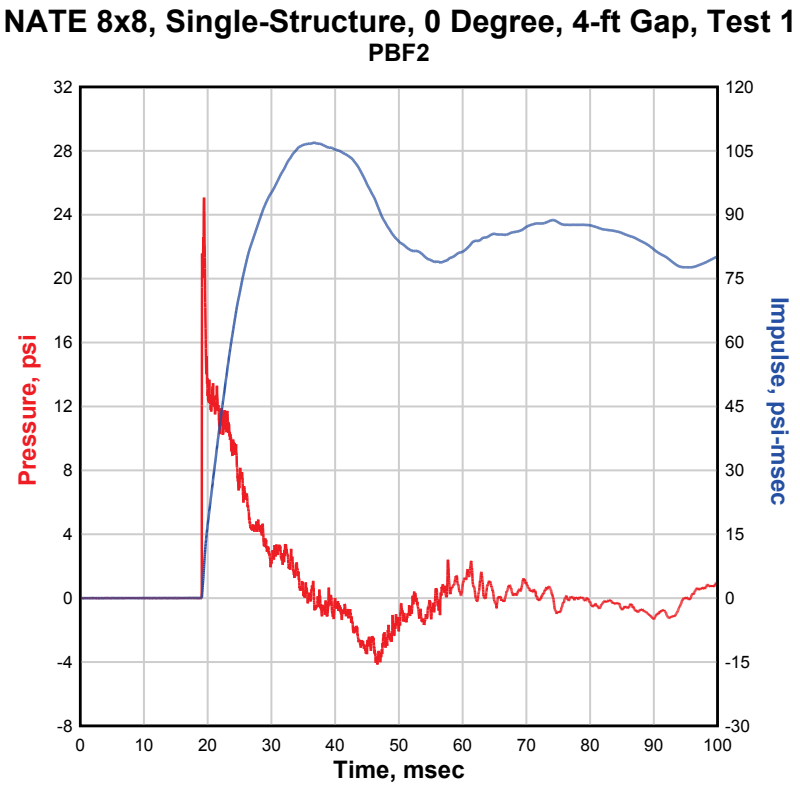
References

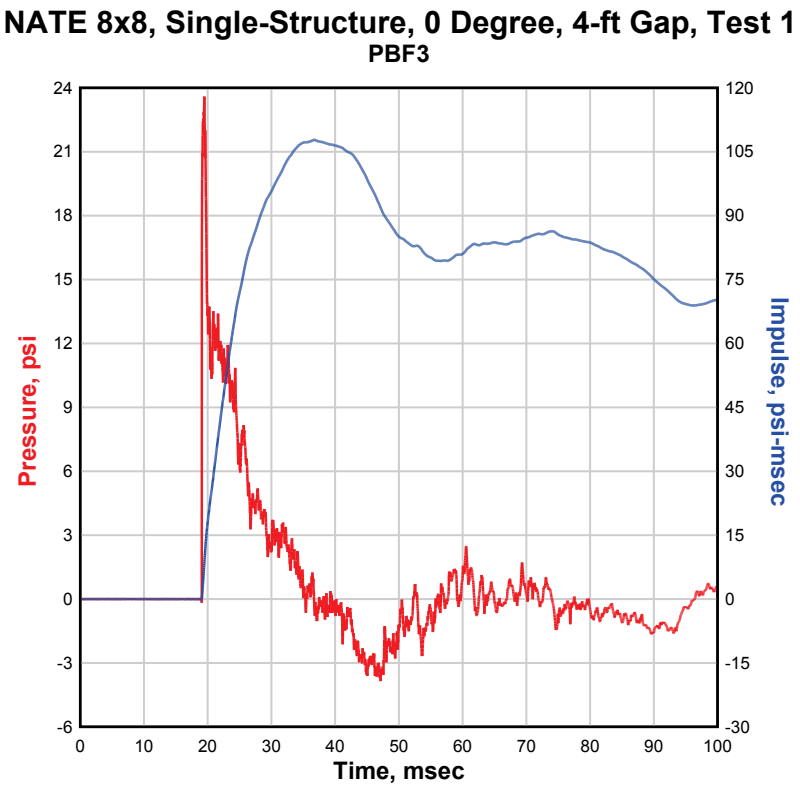
Dallriva, F. D., C. Johnson, and J. O'Daniel. 2016a. *Blast load simulator experiments for computational model validation – Report 1*. ERDC/GSL TR-16-27. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

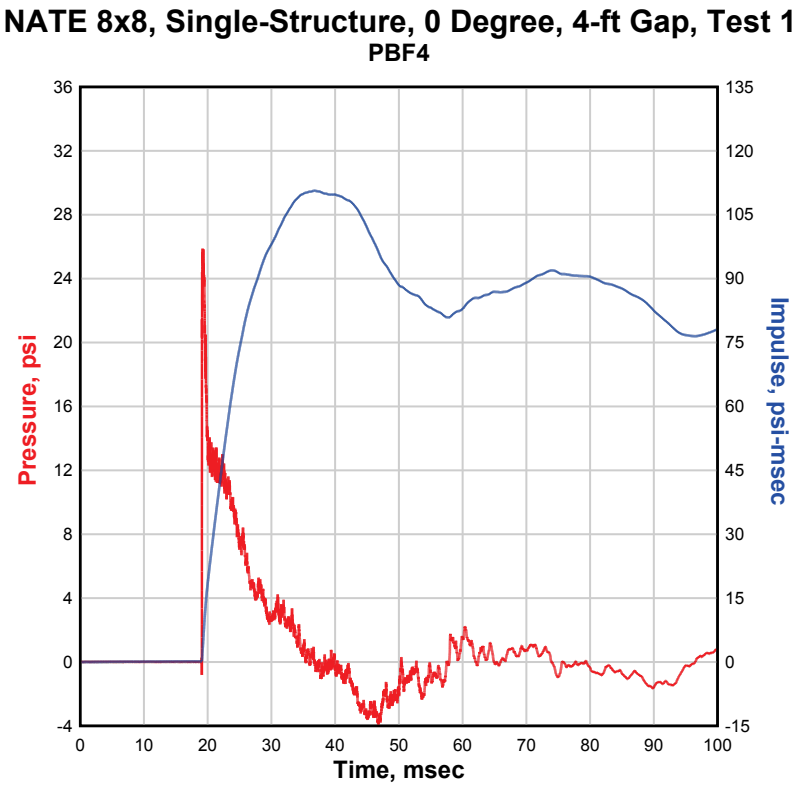
Dallriva, F. D., C. Johnson, J. O'Daniel, and A. Barnes. 2016b. *Blast load simulator experiments for computational model validation – Report 2*. ERDC/GSL TR-16-27. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

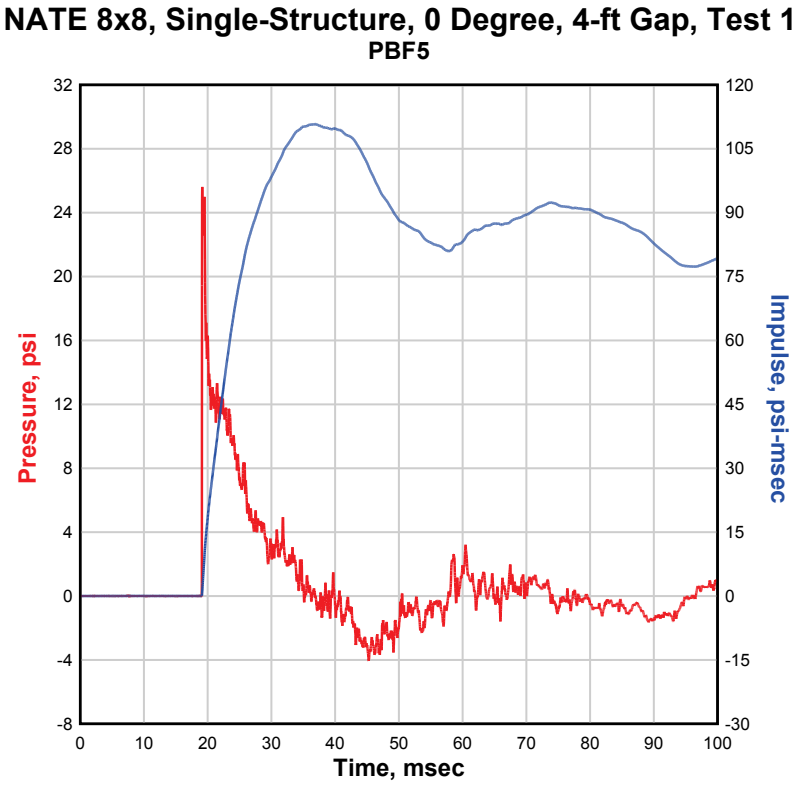
Appendix A: Pressure and Impulse Data from Tests with 0-Degree Obliquity, 4-ft Gap

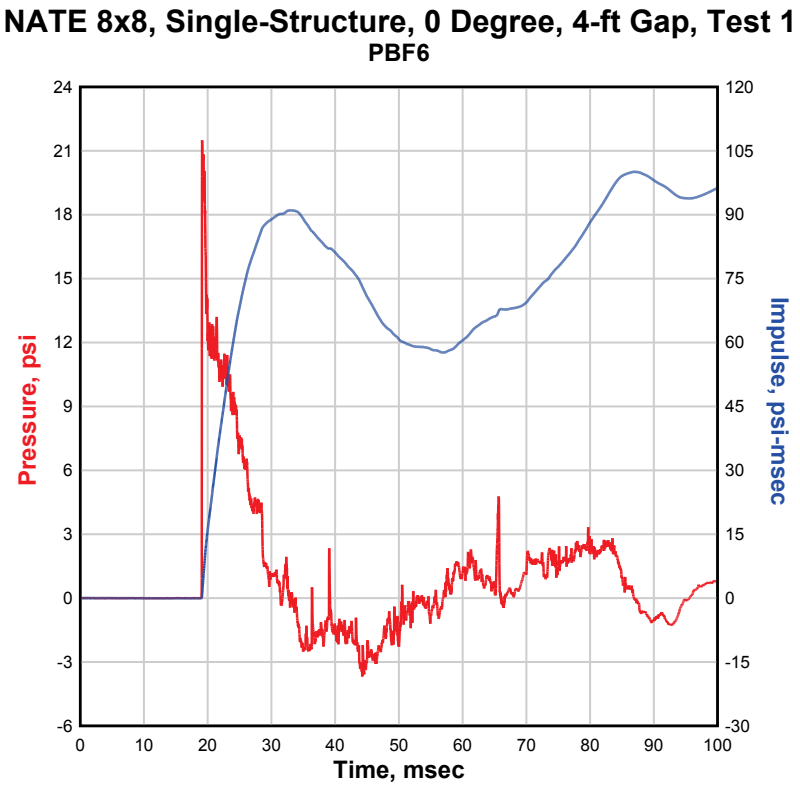


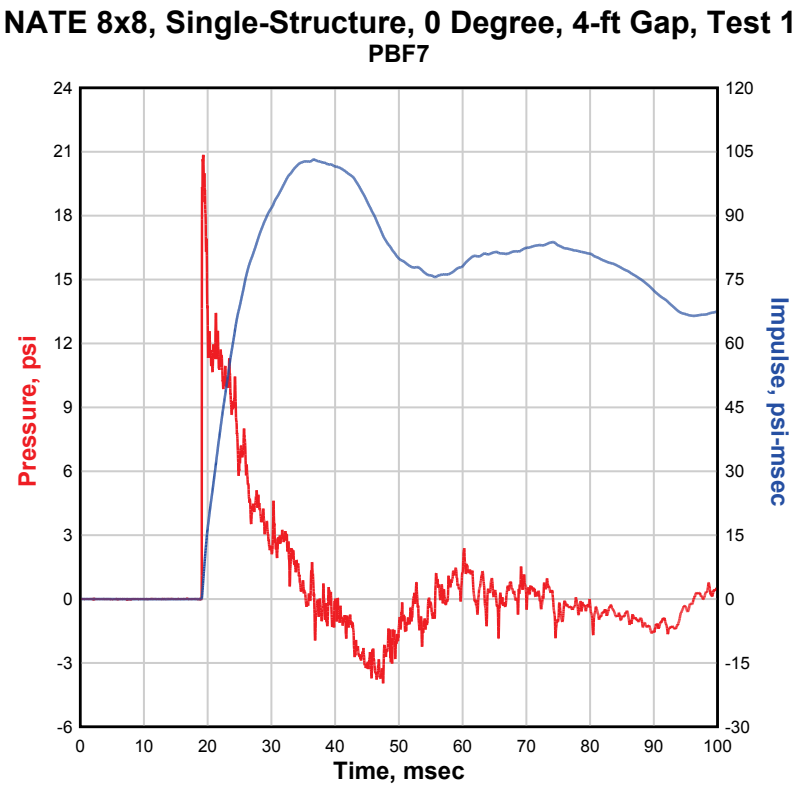

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

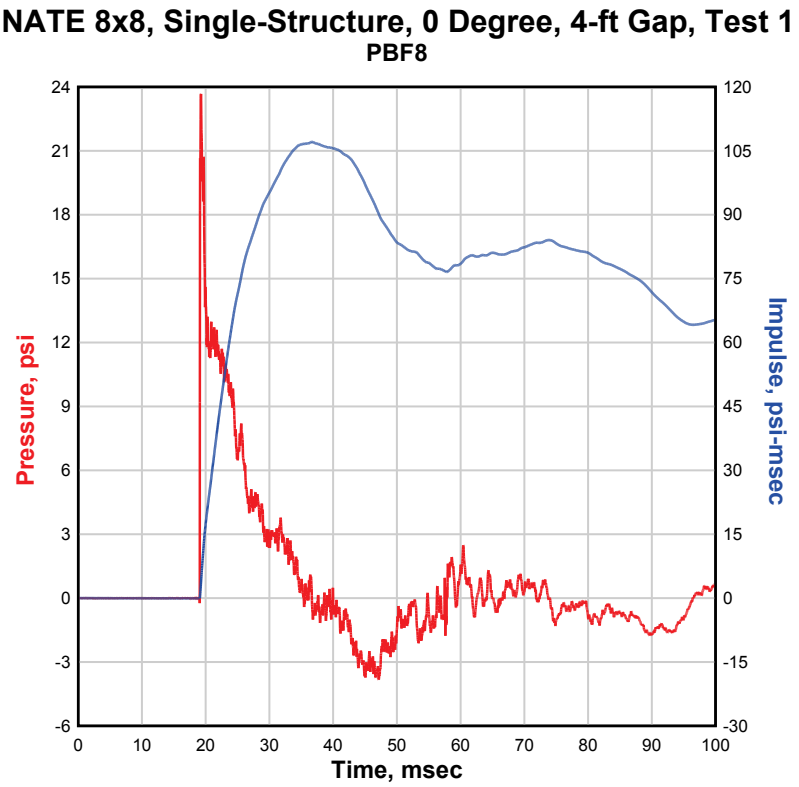

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

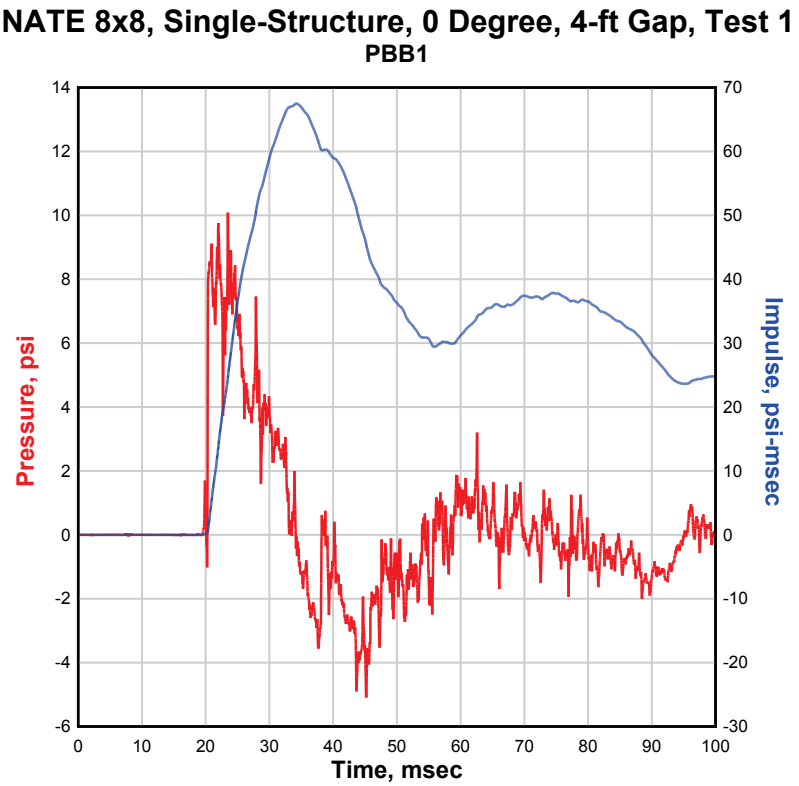

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

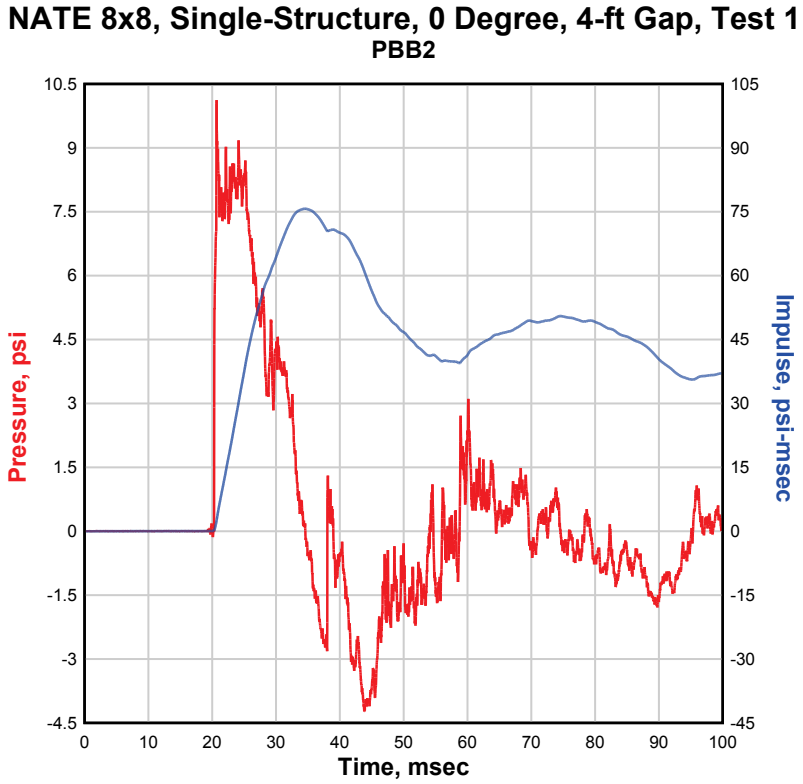

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
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-30
-45
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10
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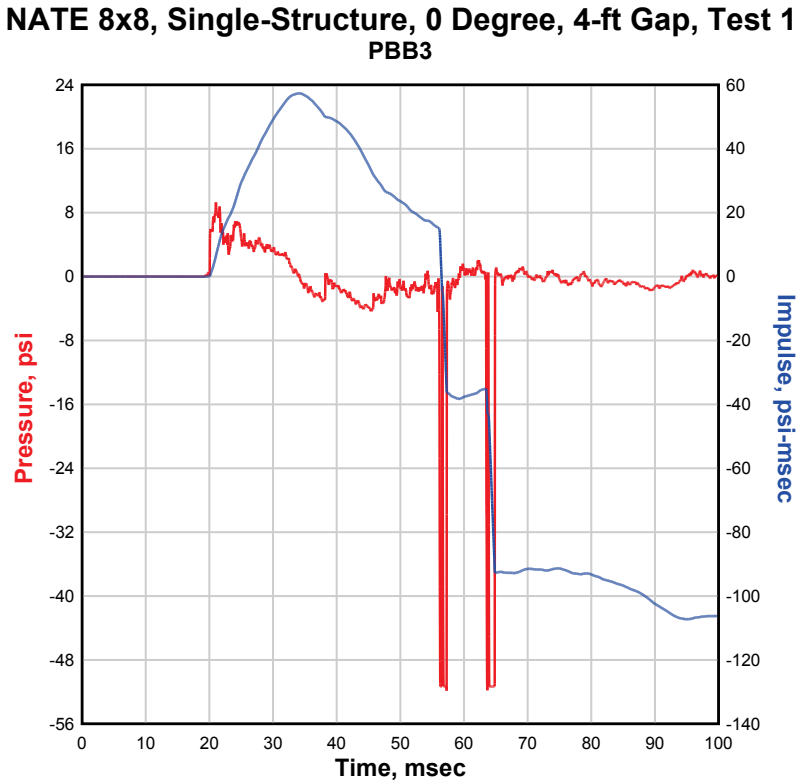
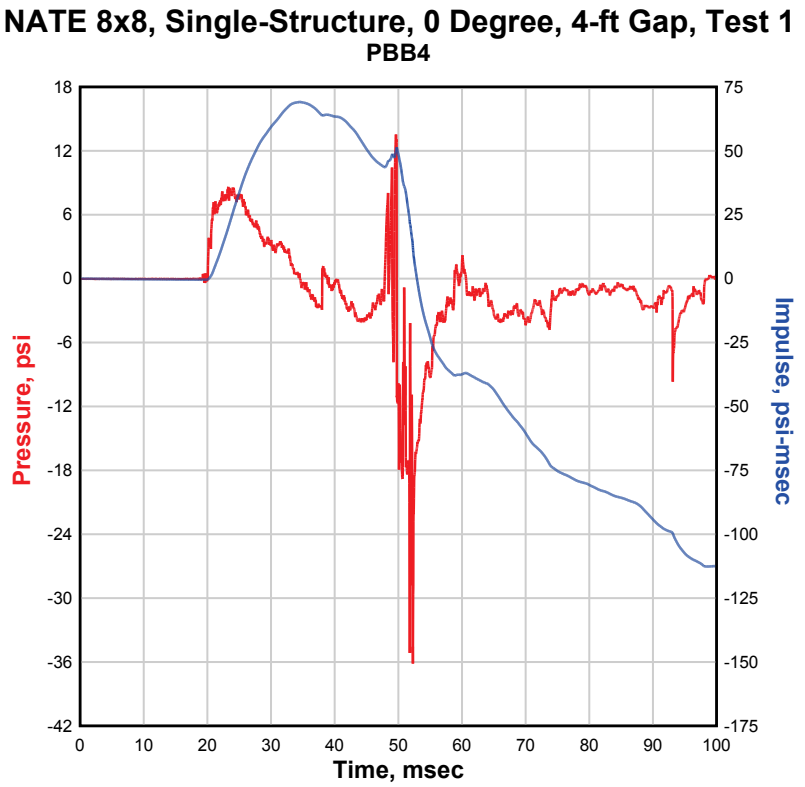
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
18
12
6
0
-6
-12
-18
-24
-30
-36
-42
75
50
25
0
-25
-50
-75
-100
-125
-150
-175
0
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30
40
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70
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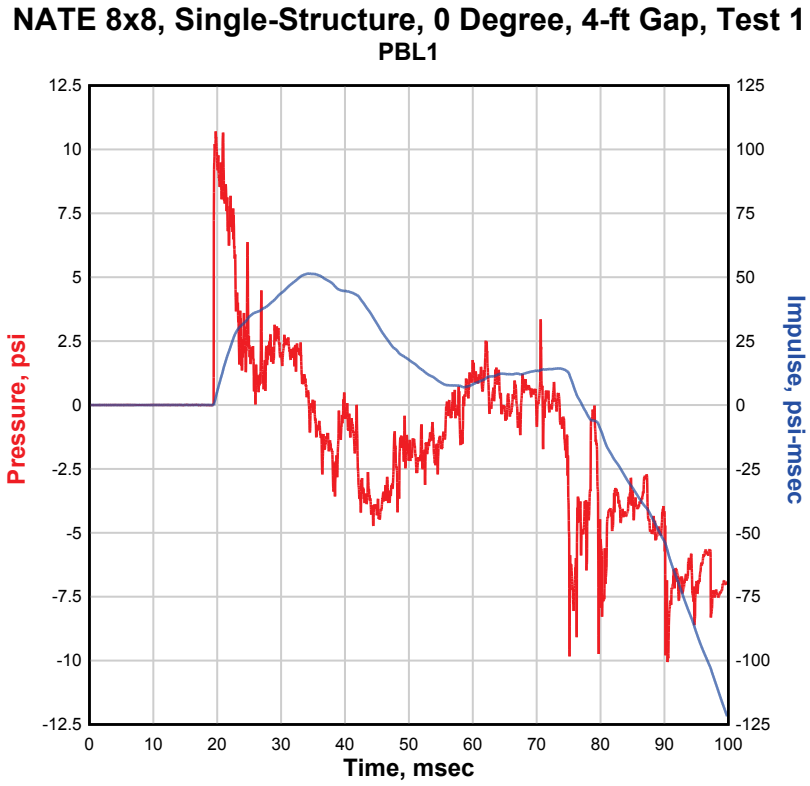
90
100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PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
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10
7.5
5
2.5
0
-2.5
-5
-7.5
-10
-12.5
125
100
75
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30
40
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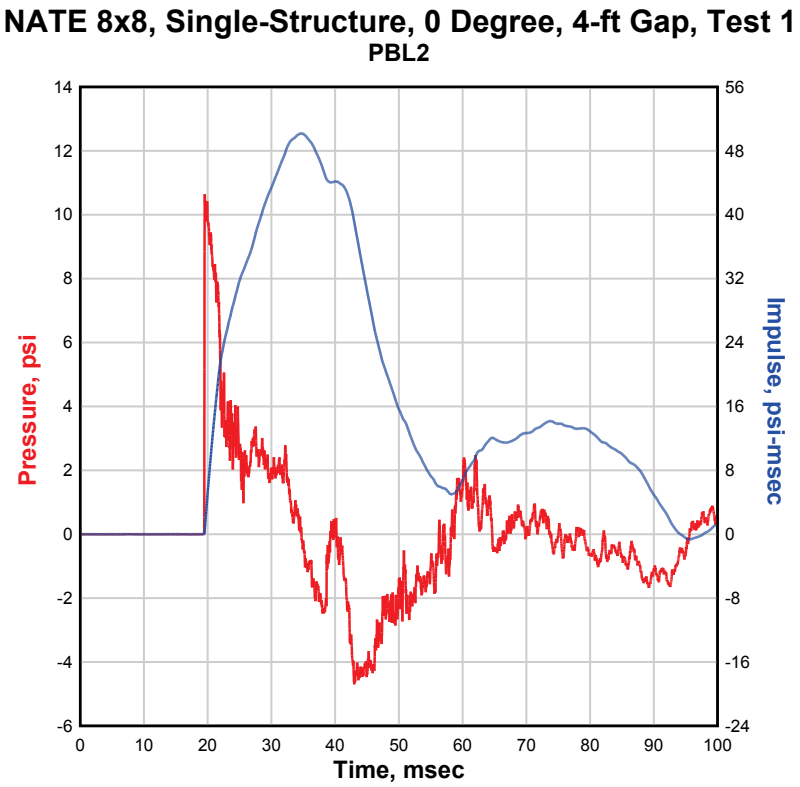
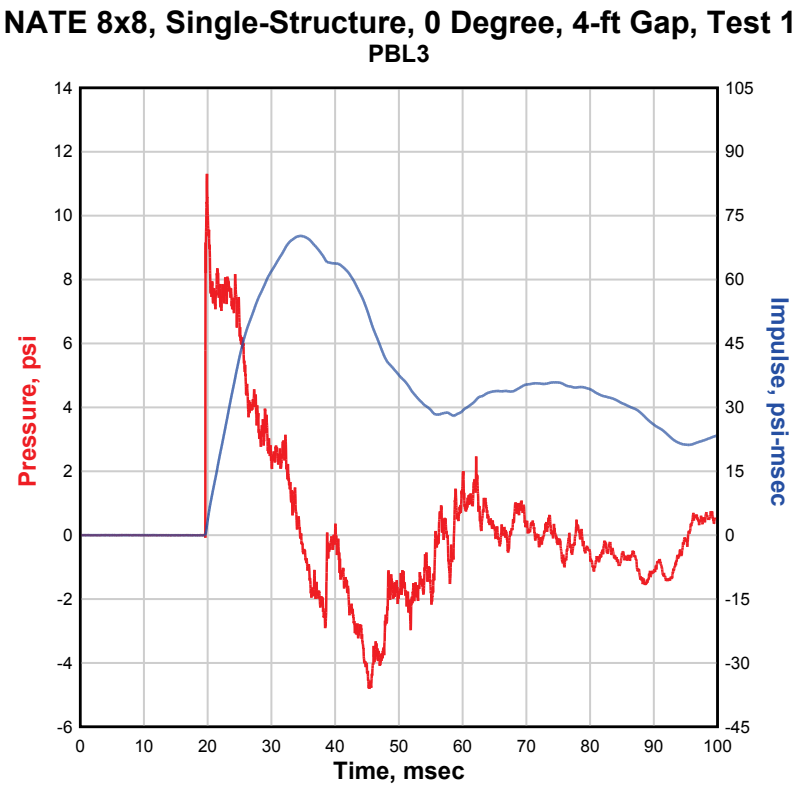
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
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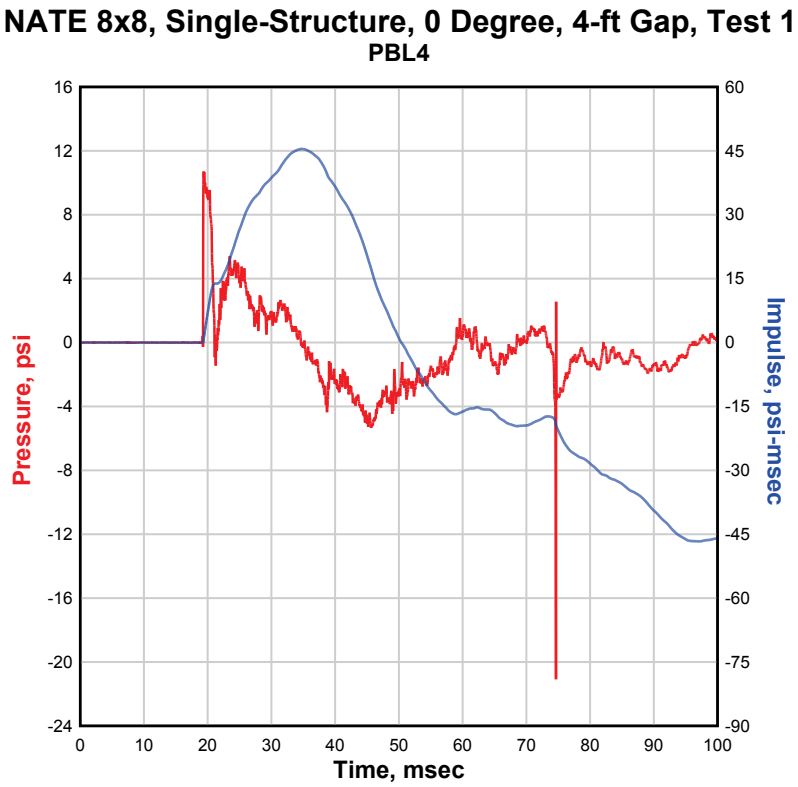
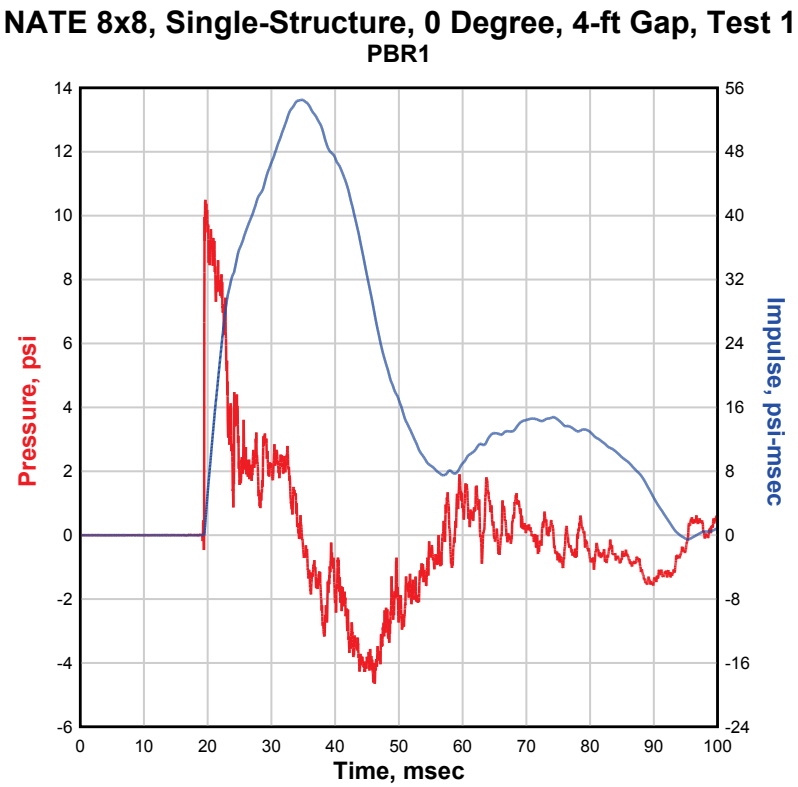
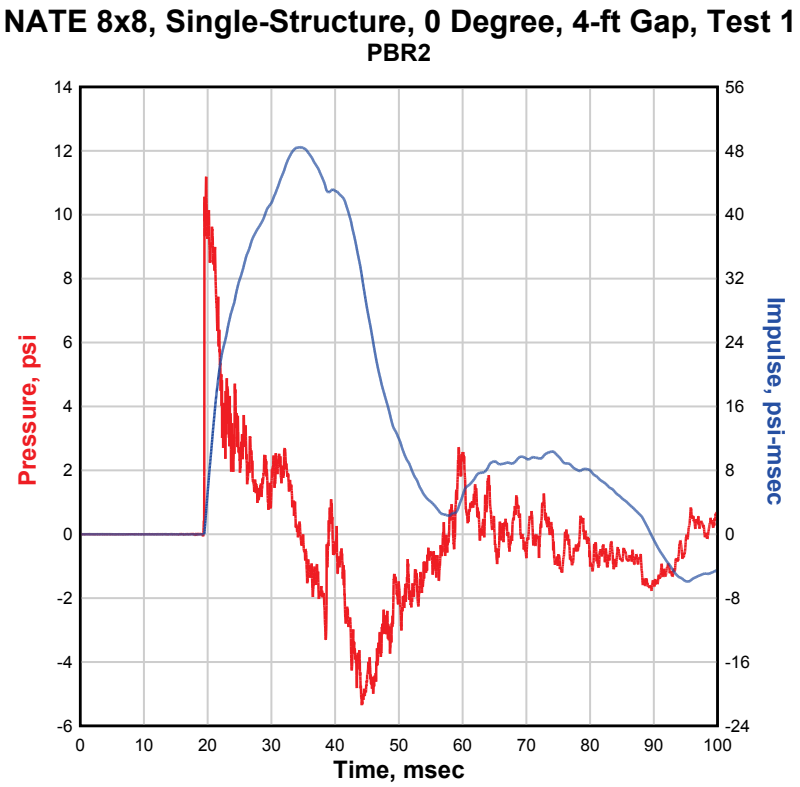

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
16
12
8
4
0
-4
-8
-12
-16
-20
-24
60
45
30
15
0
-15
-30
-45
-60
-75
-90
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
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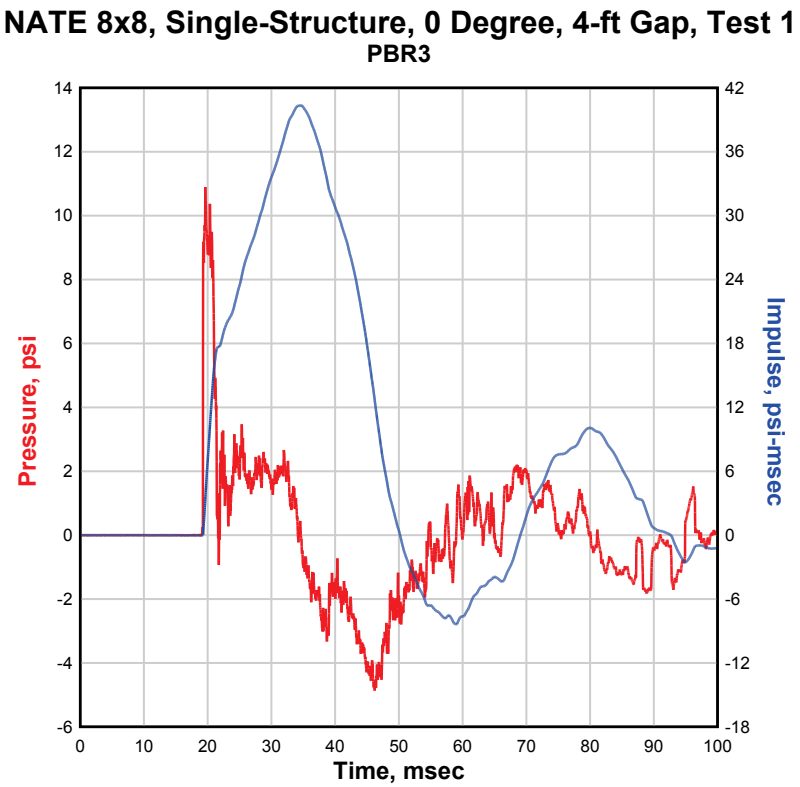
NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
42
36
30
24
18
12
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-18
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30
40
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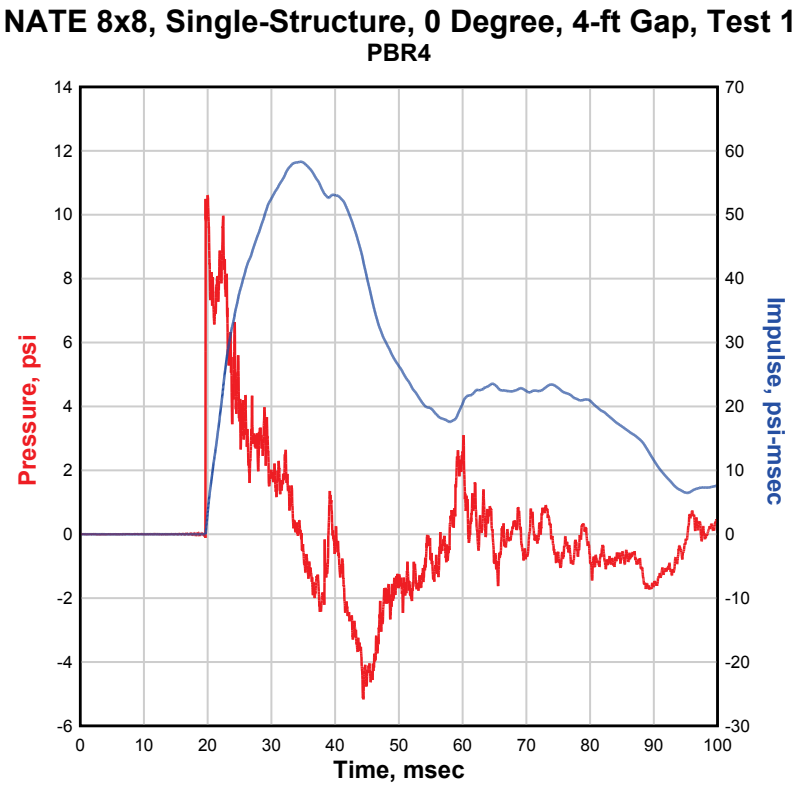
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
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30
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90
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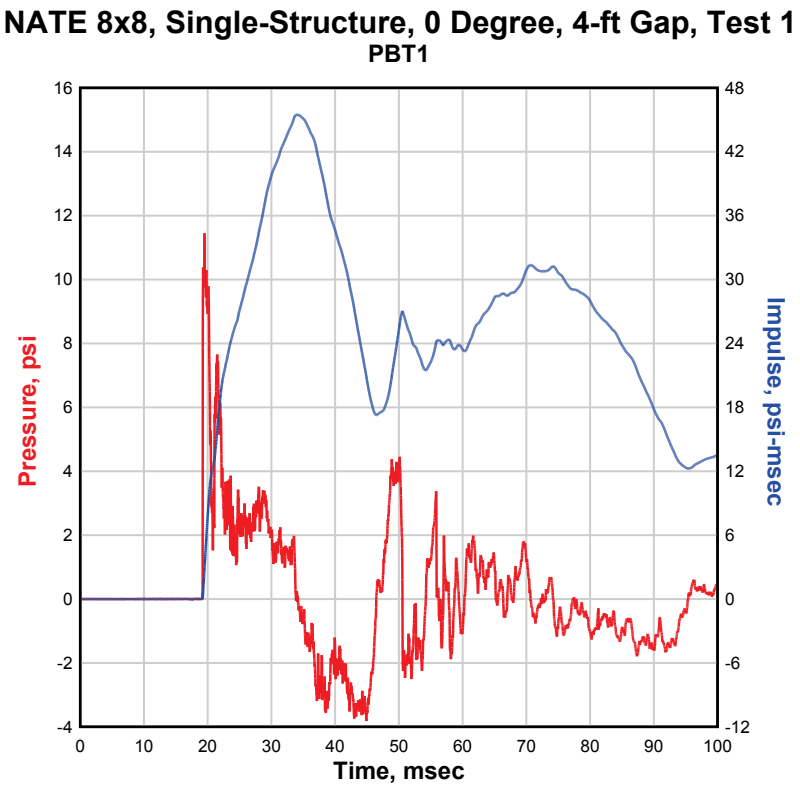
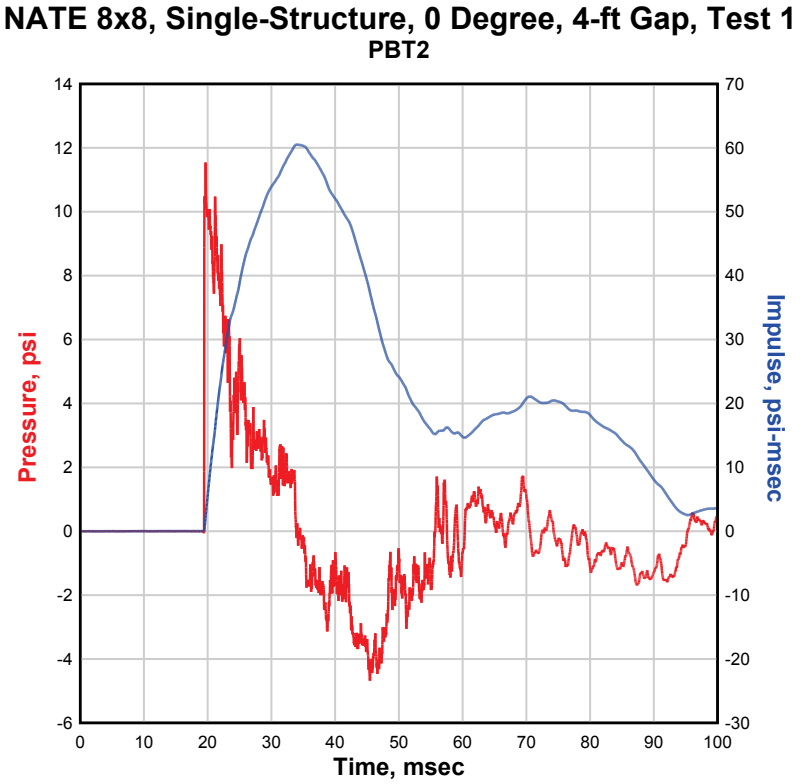
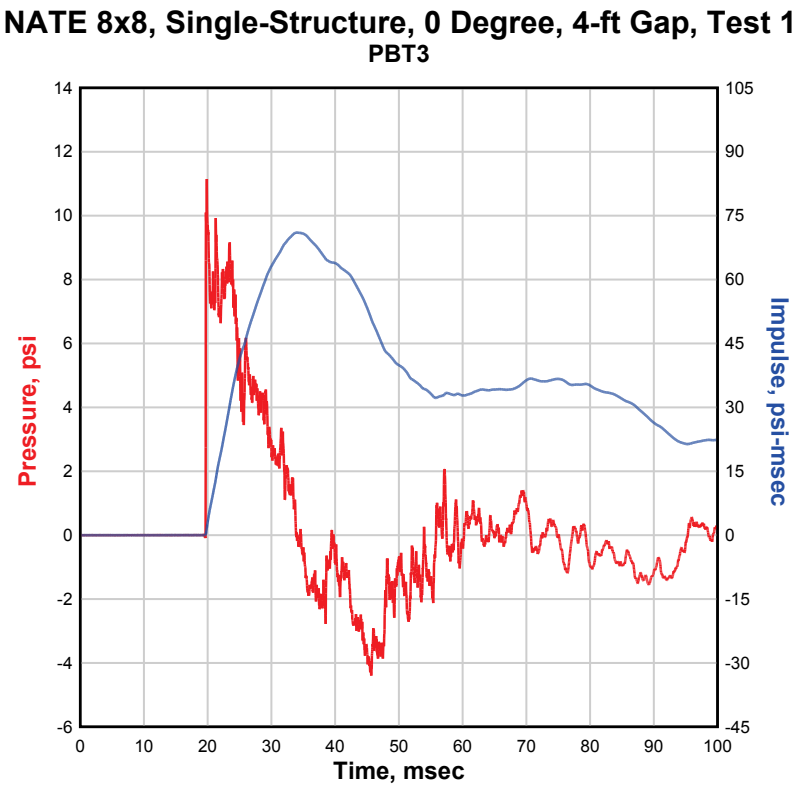
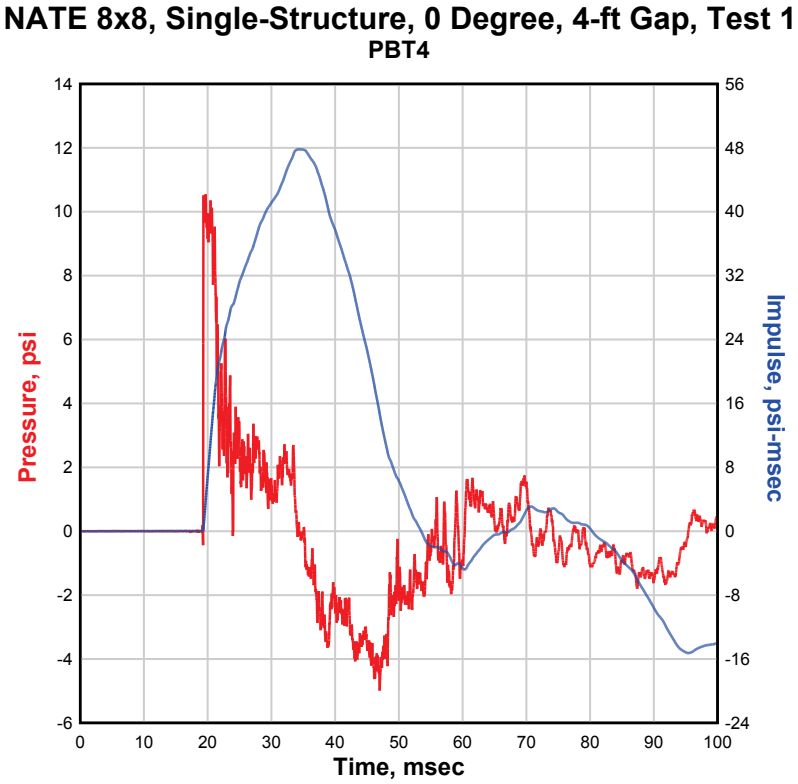
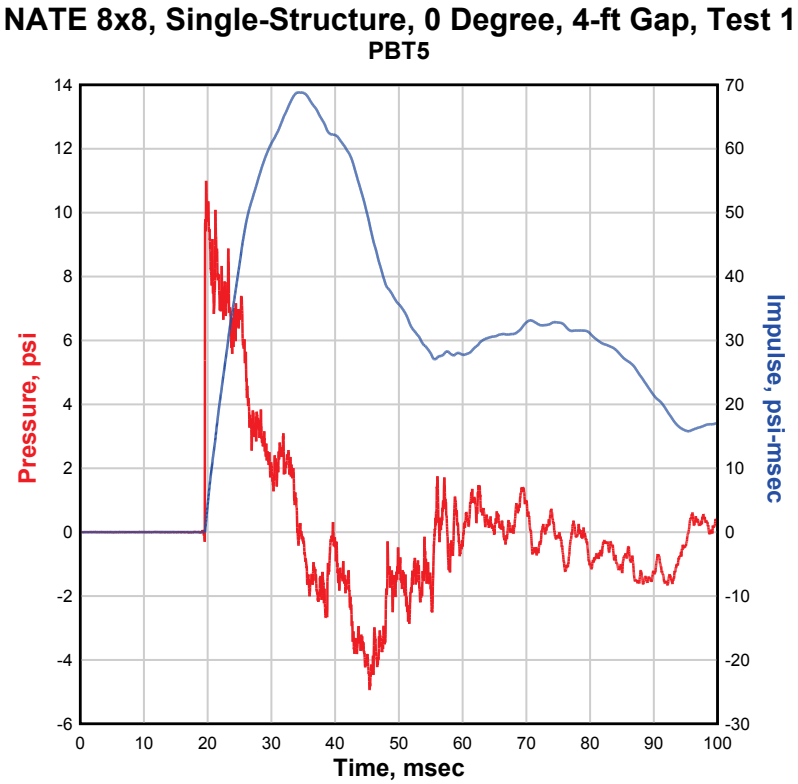
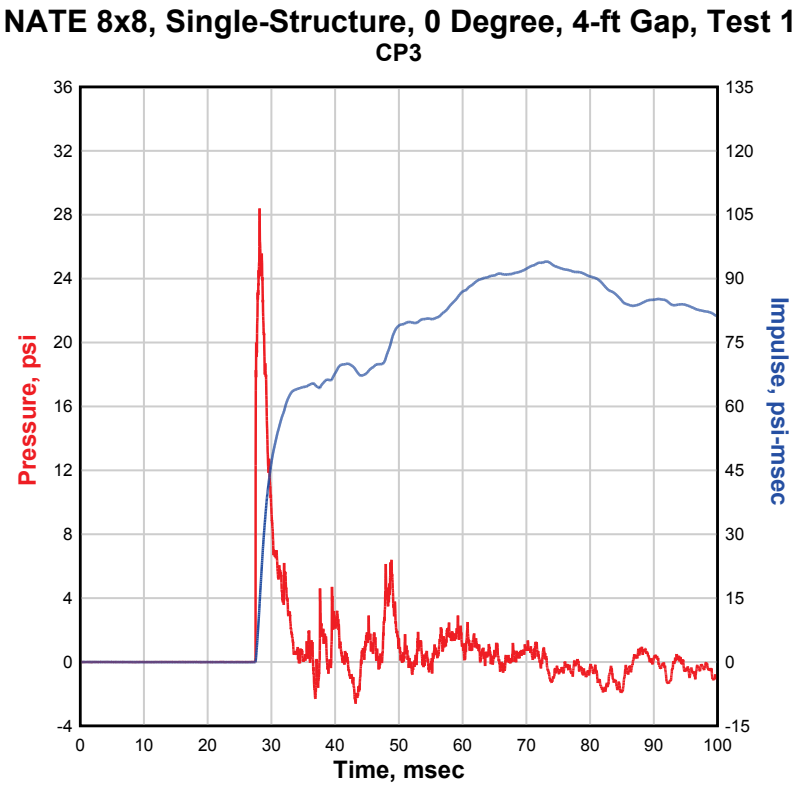

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
48
42
36
30
24
18
12
6
0
-6
-12
0
10
20
30
40
50
60
70
80
90
100

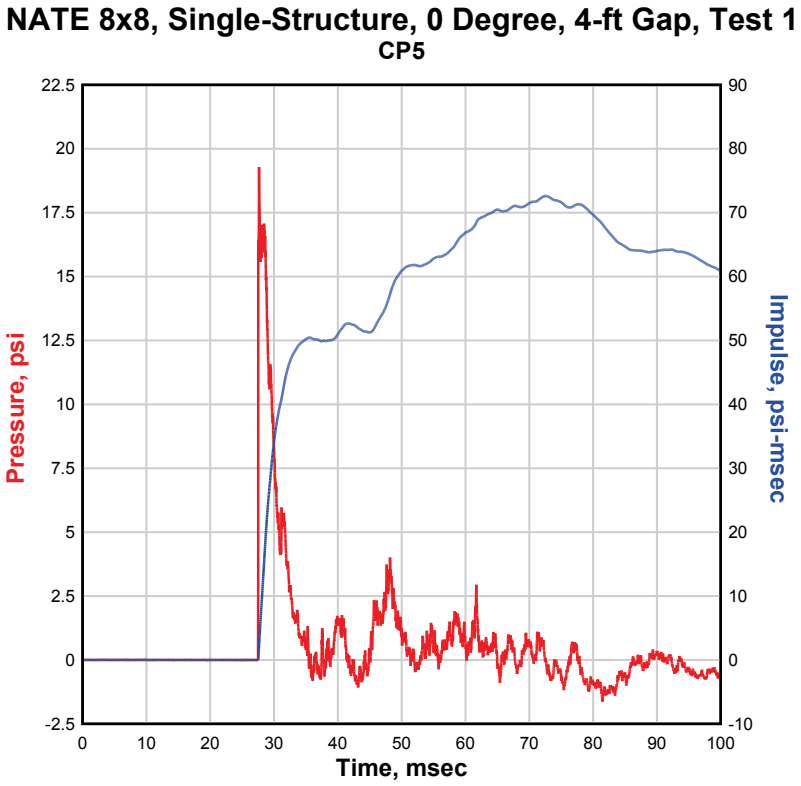

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

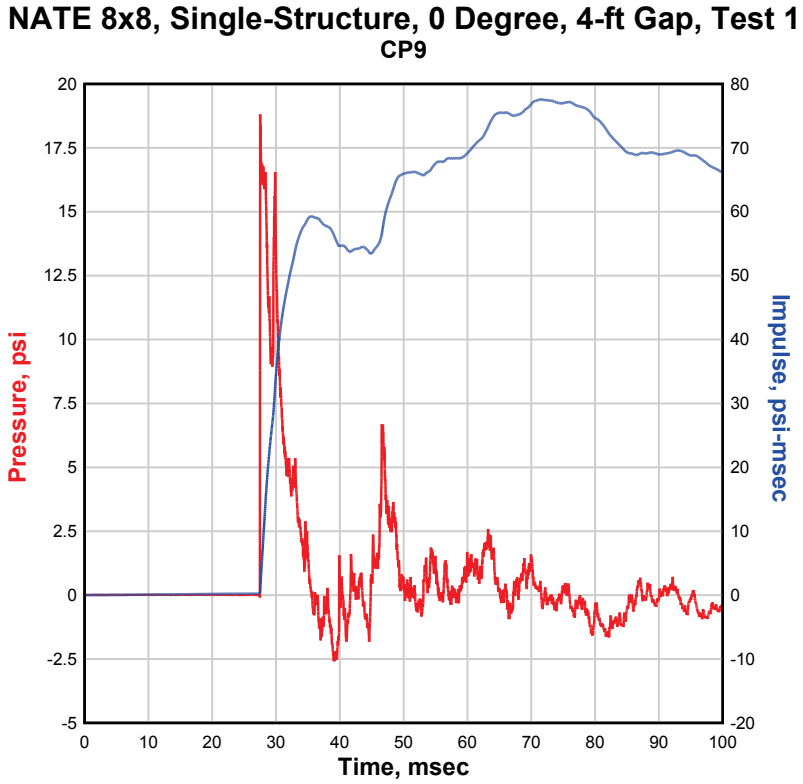

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

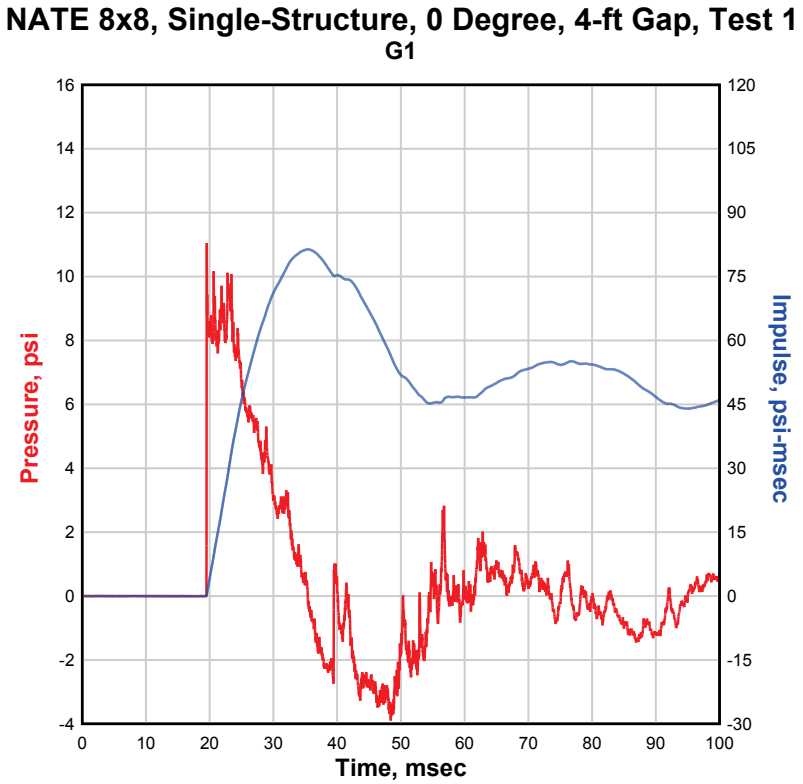

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

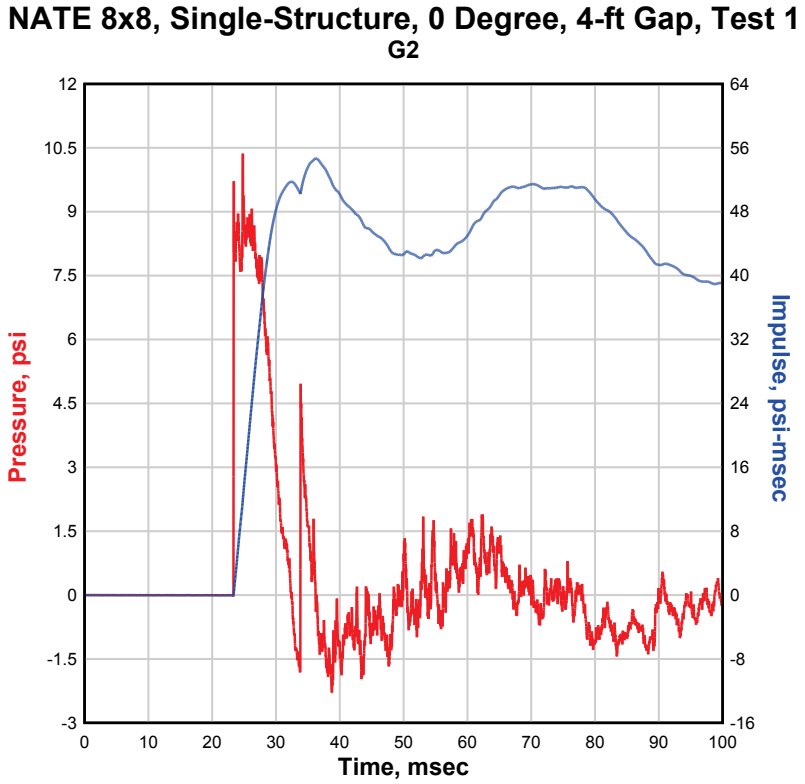

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

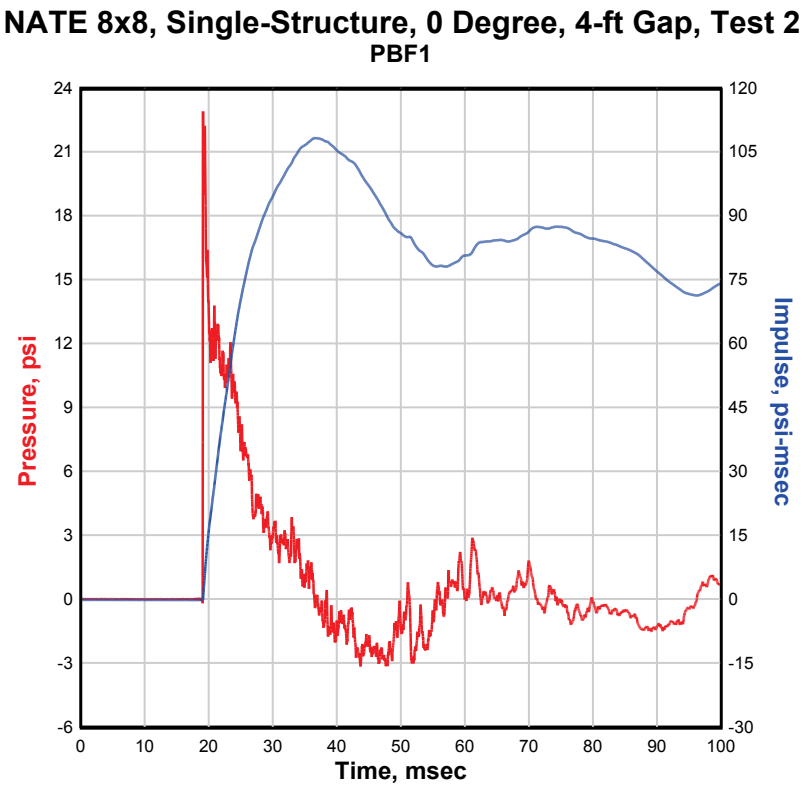

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

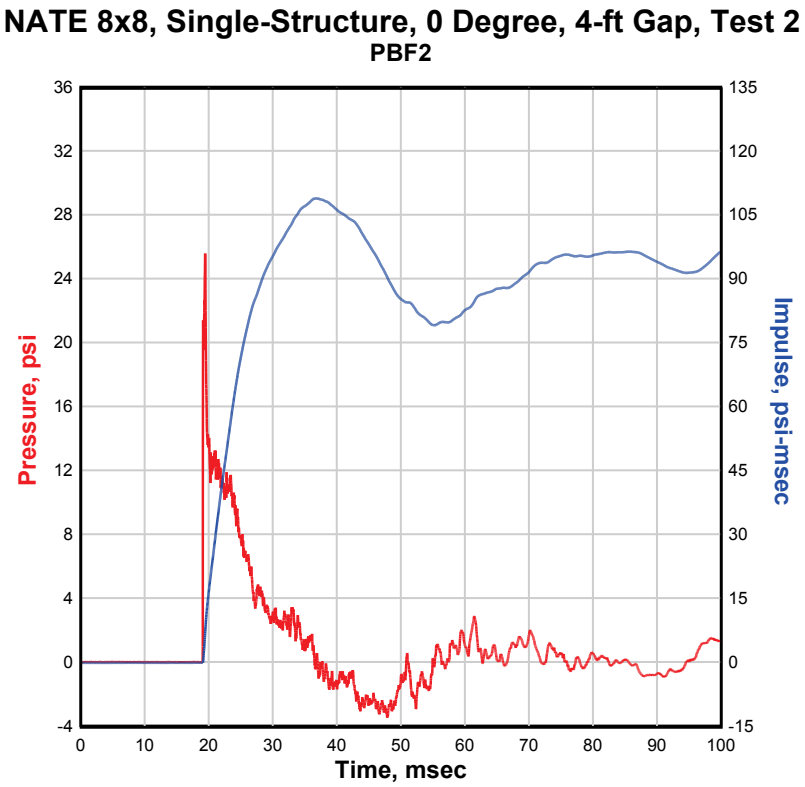

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

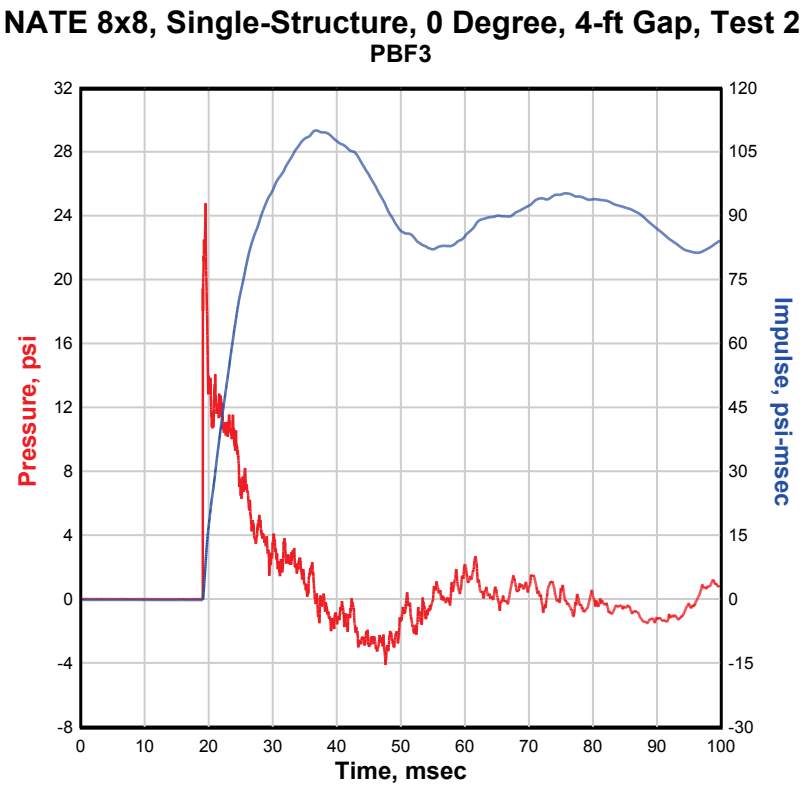

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
80
70
60
50
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100

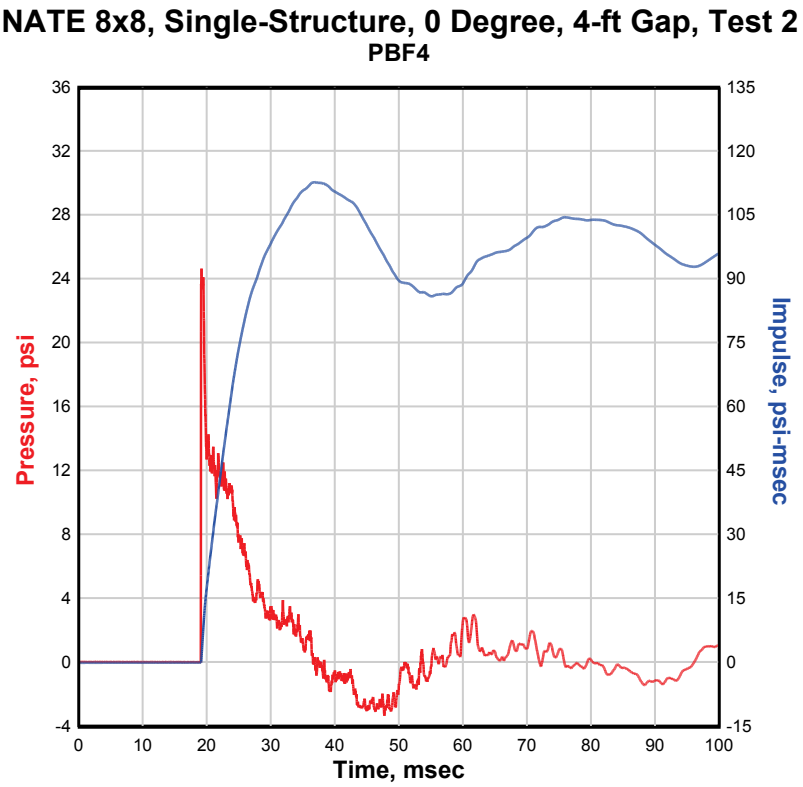

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
G1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

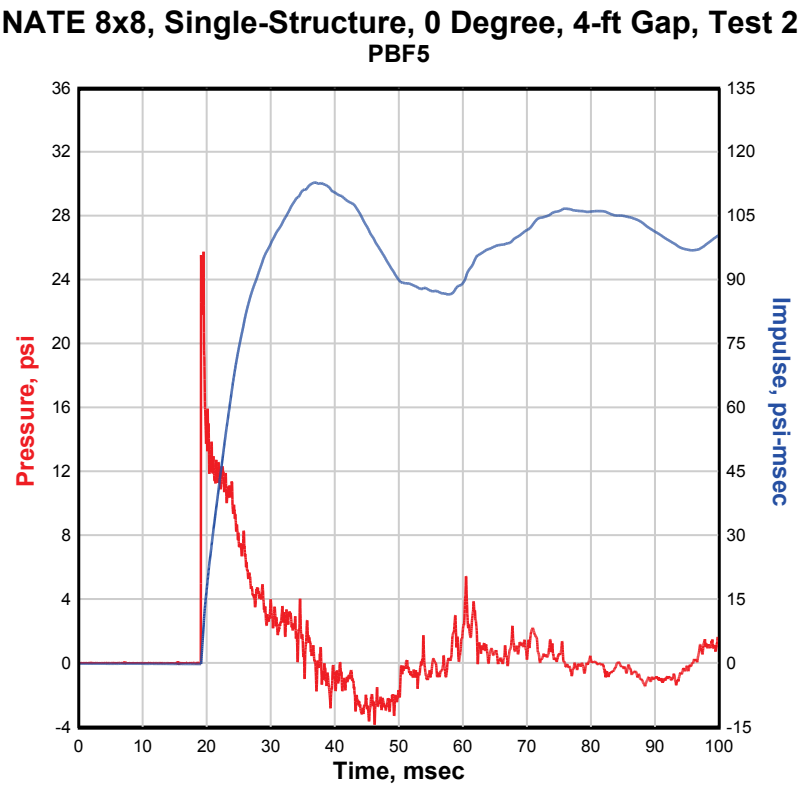

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 1
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

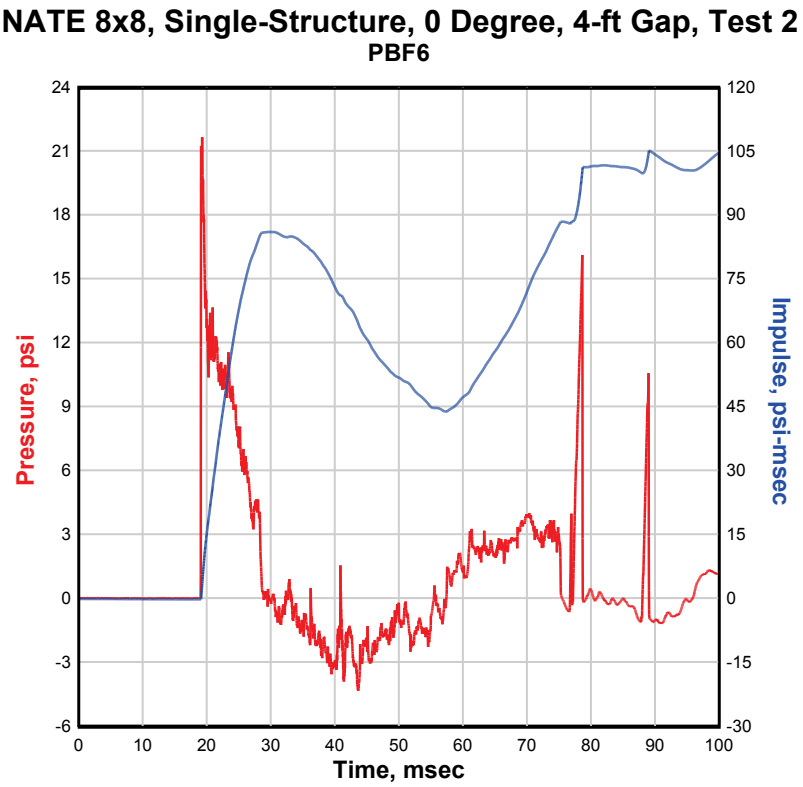

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

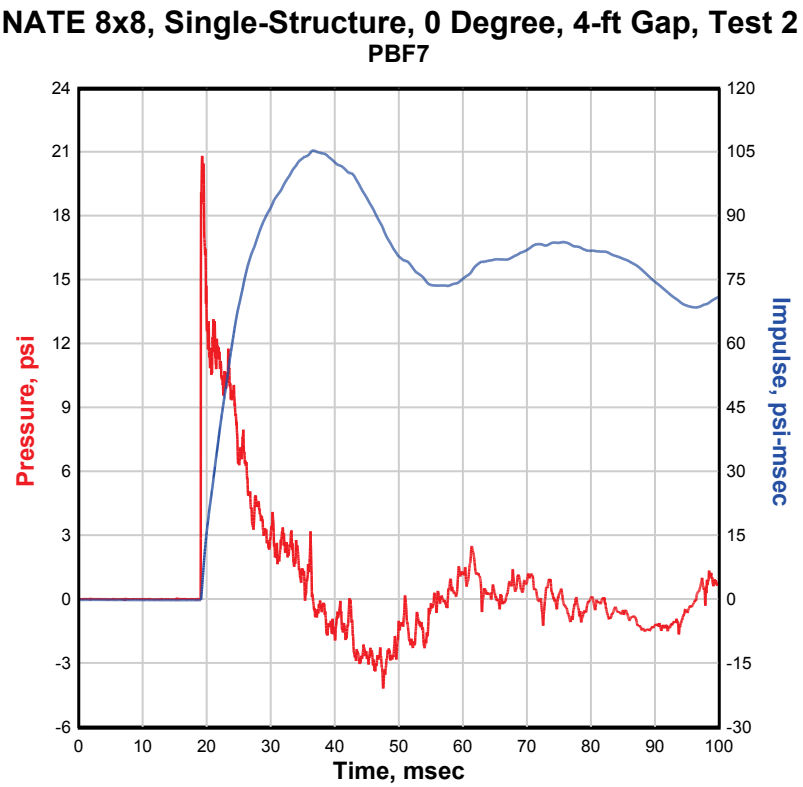

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

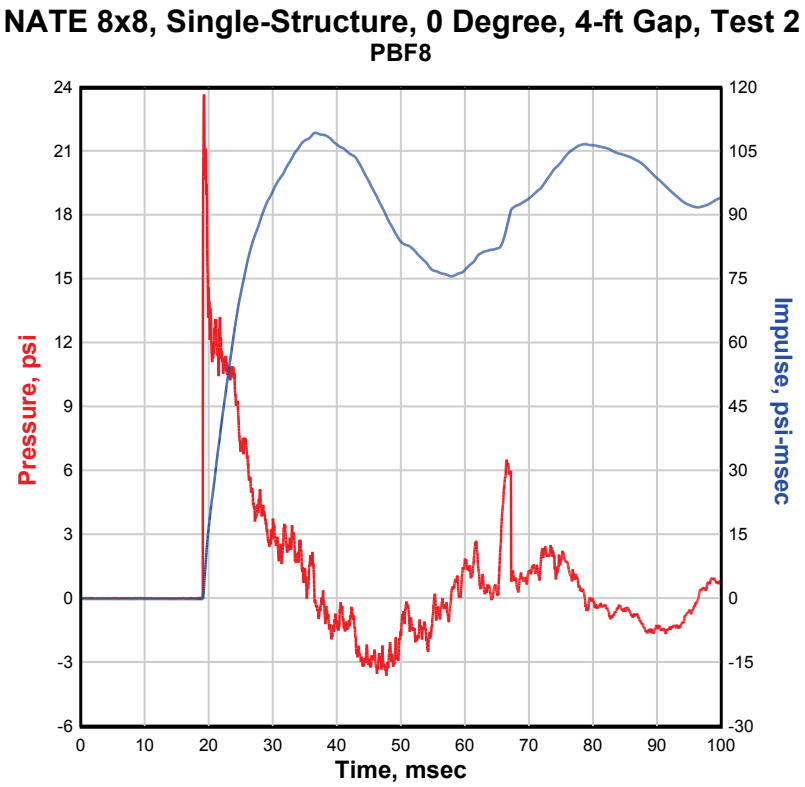

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

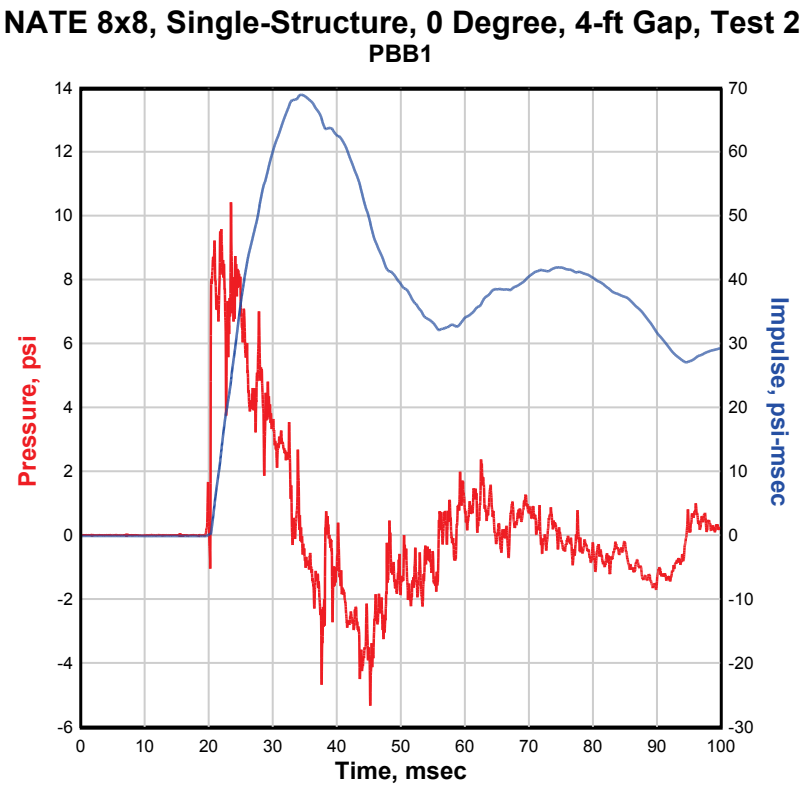

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

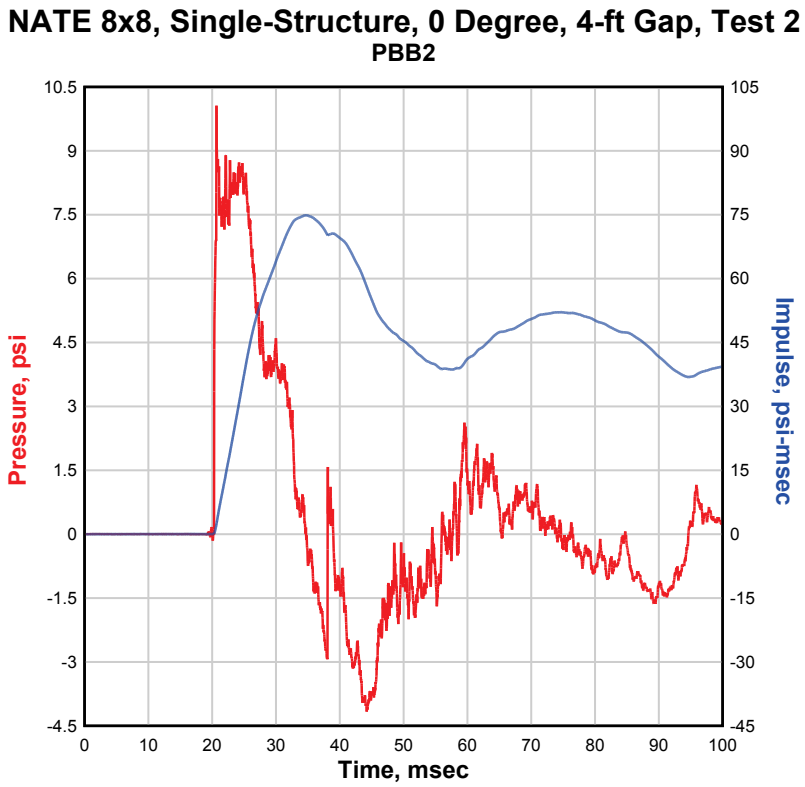

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

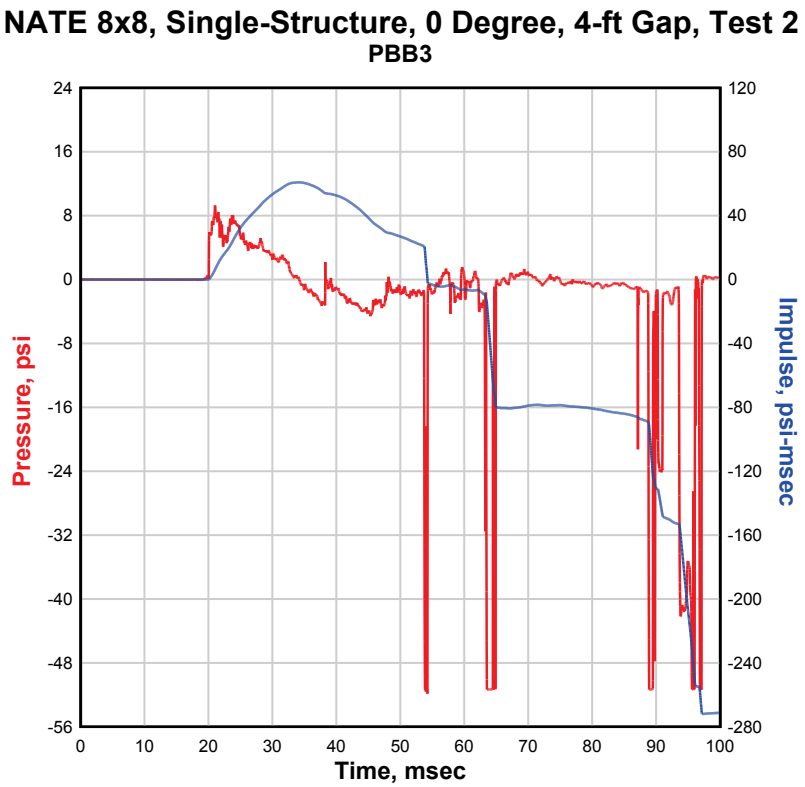

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

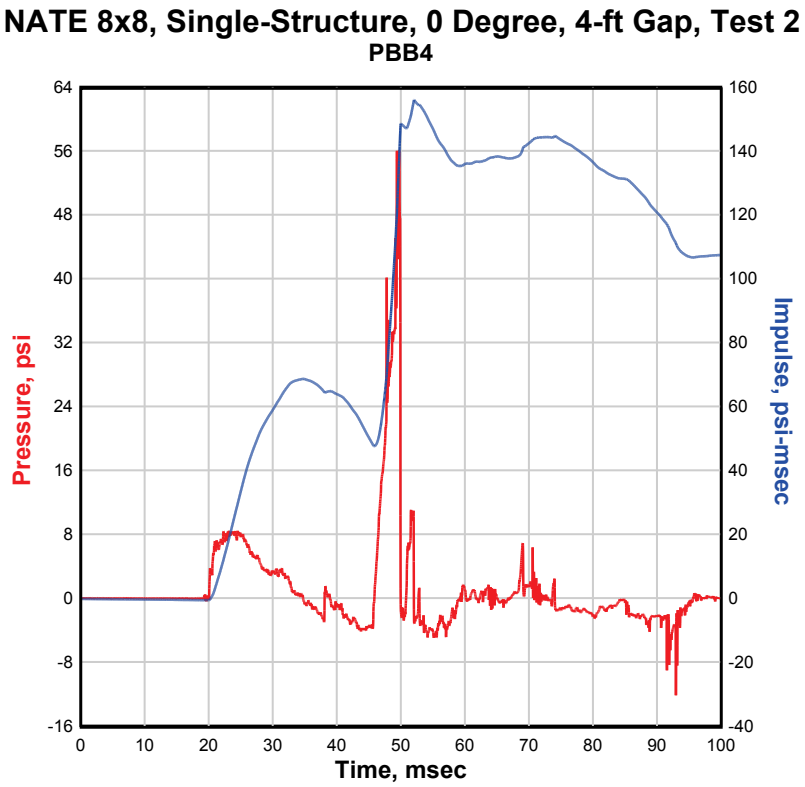

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

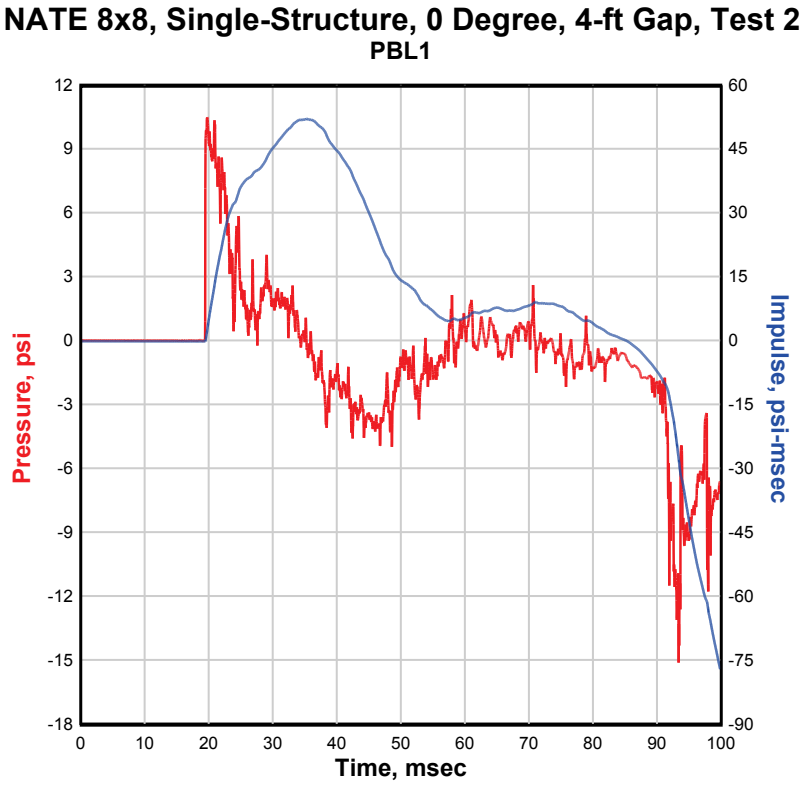

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

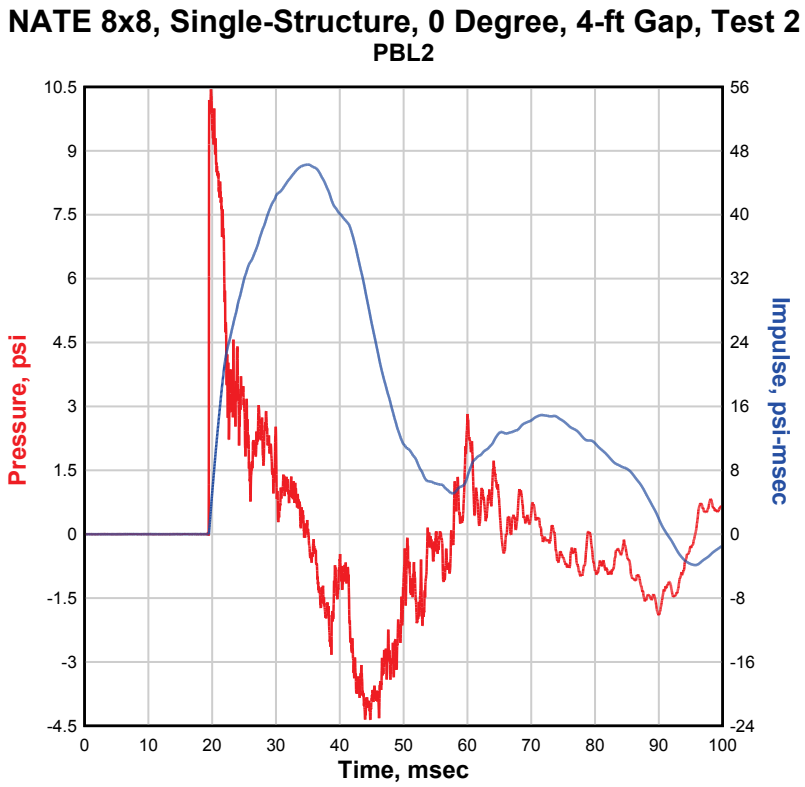

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

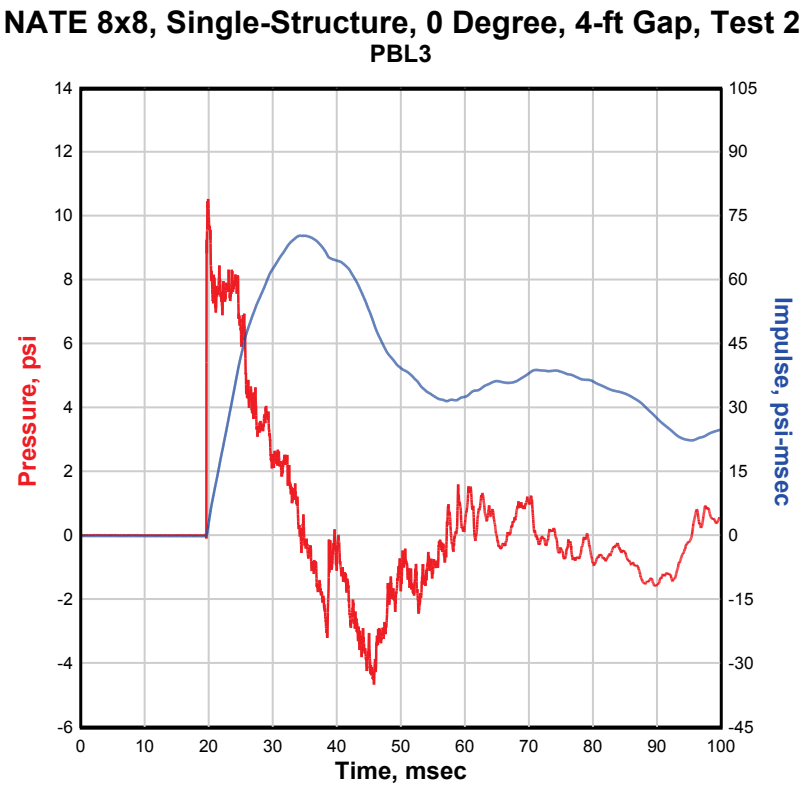

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

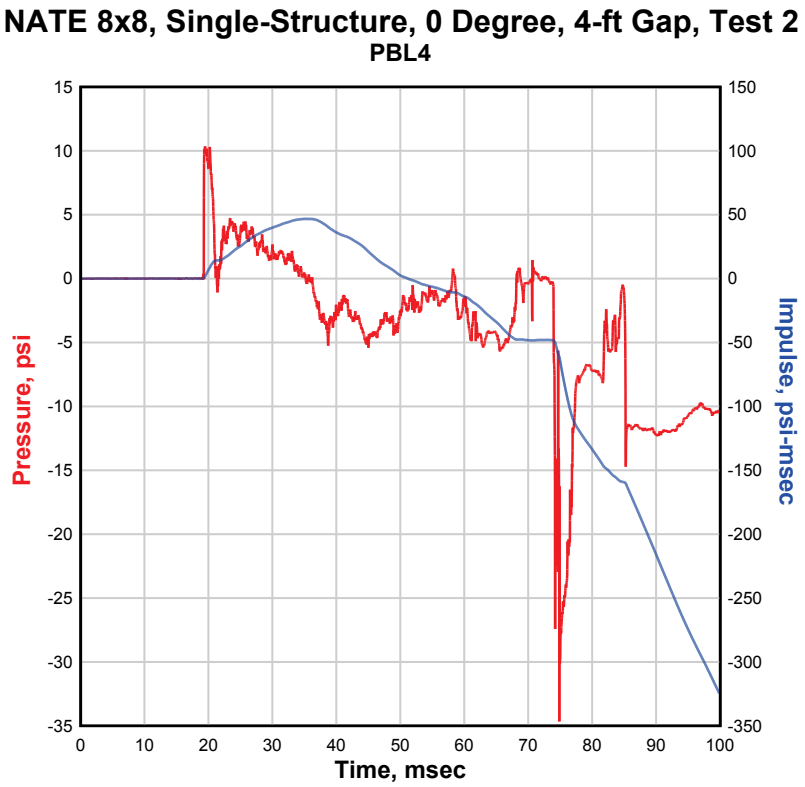

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
120
80
40
0
-40
-80
-120
-160
-200
-240
-280
0
10
20
30
40
50
60
70
80
90
100

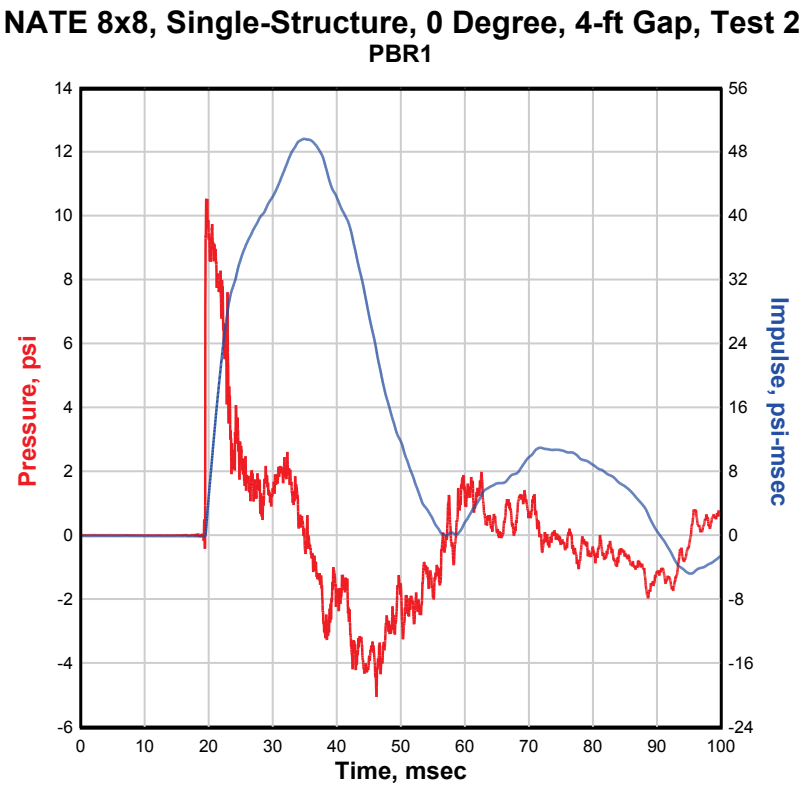

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
64
56
48
40
32
24
16
8
0
-8
-16
160
140
120
100
80
60
40
20
0
-20
-40
0
10
20
30
40
50
60
70
80
90
100

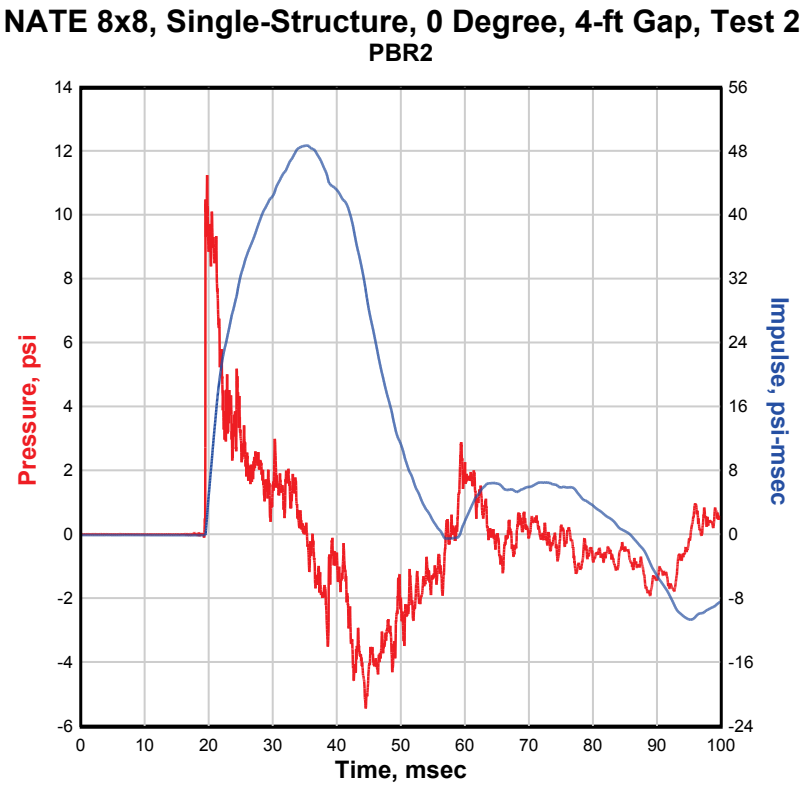

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
12
9
6
3
0
-3
-6
-9
-12
-15
-18
60
45
30
15
0
-15
-30
-45
-60
-75
-90
0
10
20
30
40
50
60
70
80
90
100

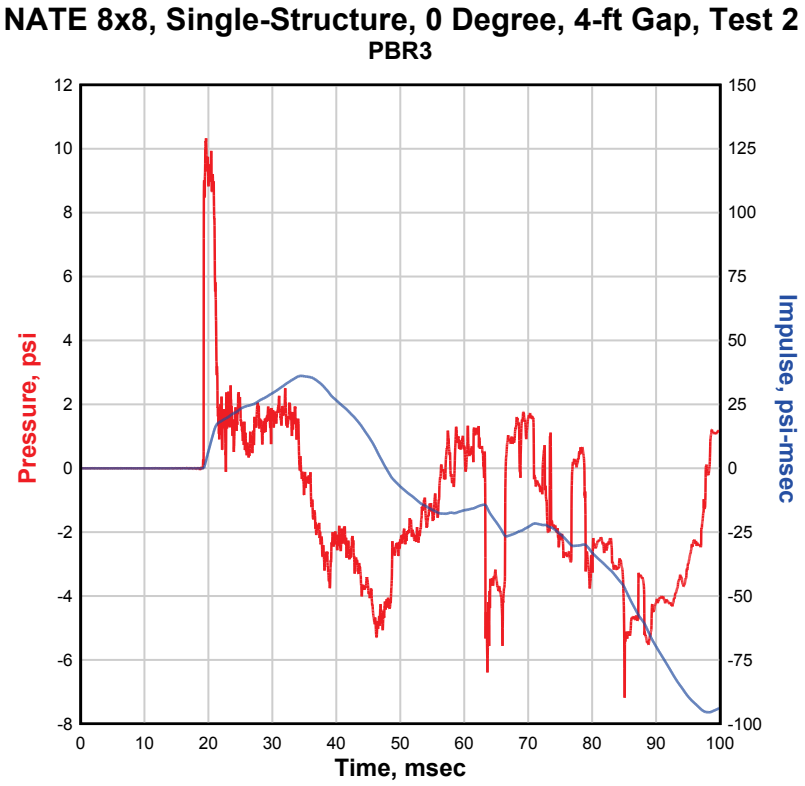

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

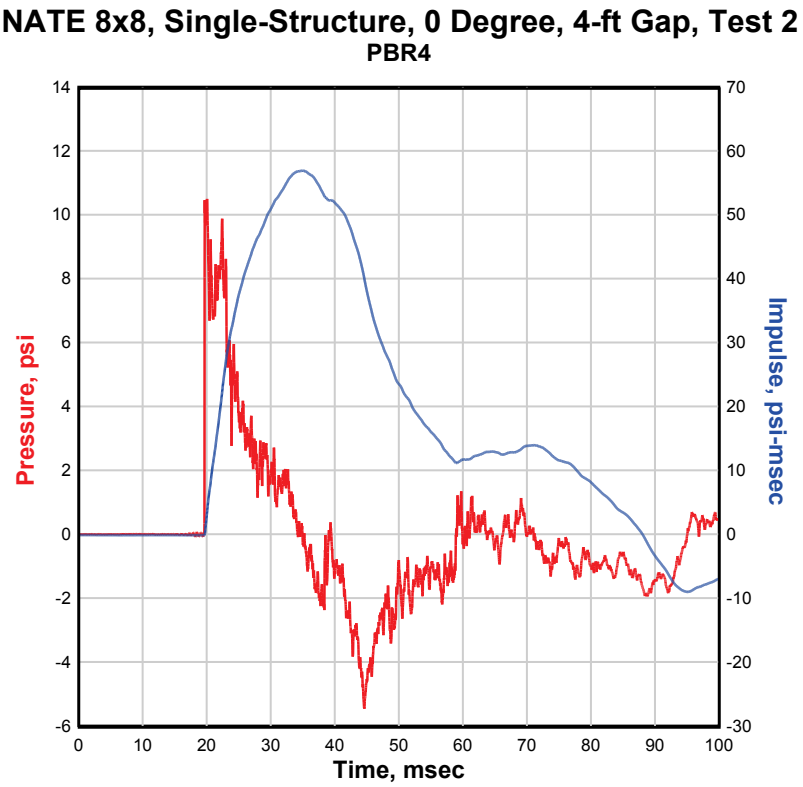

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

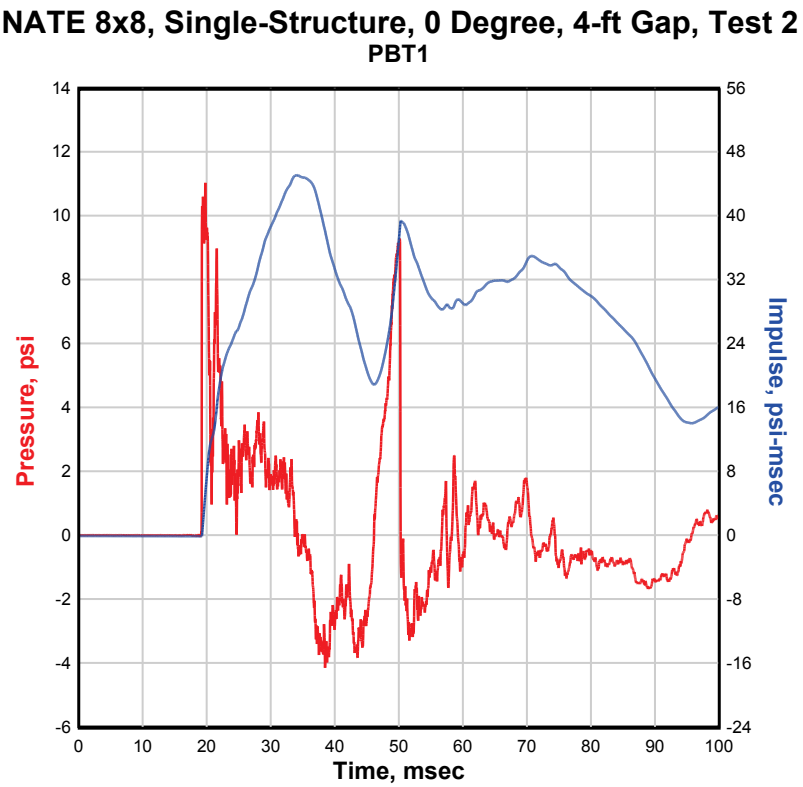

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
0
10
20
30
40
50
60
70
80
90
100

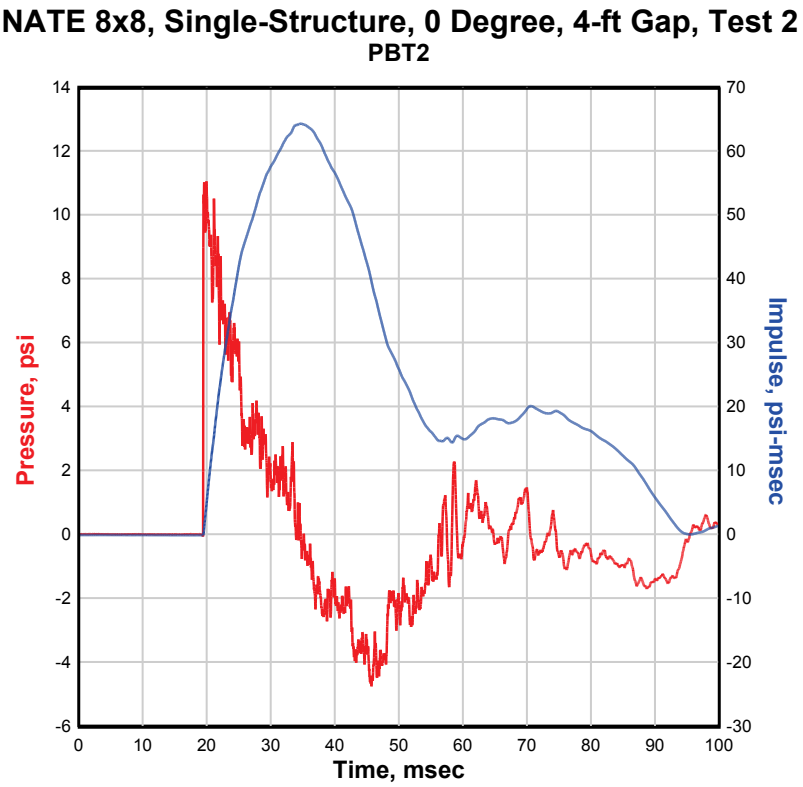

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

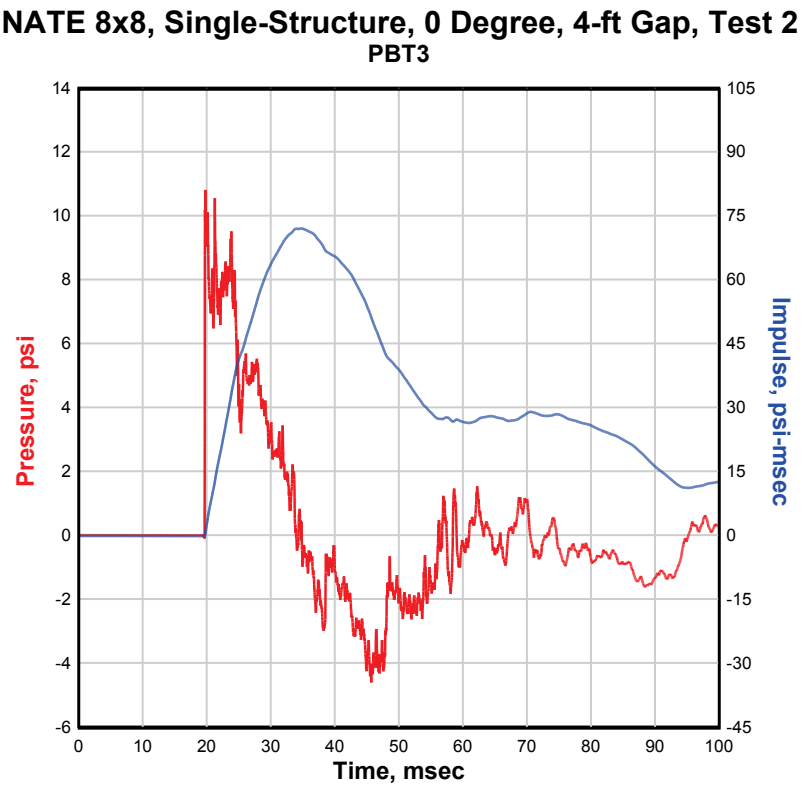

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

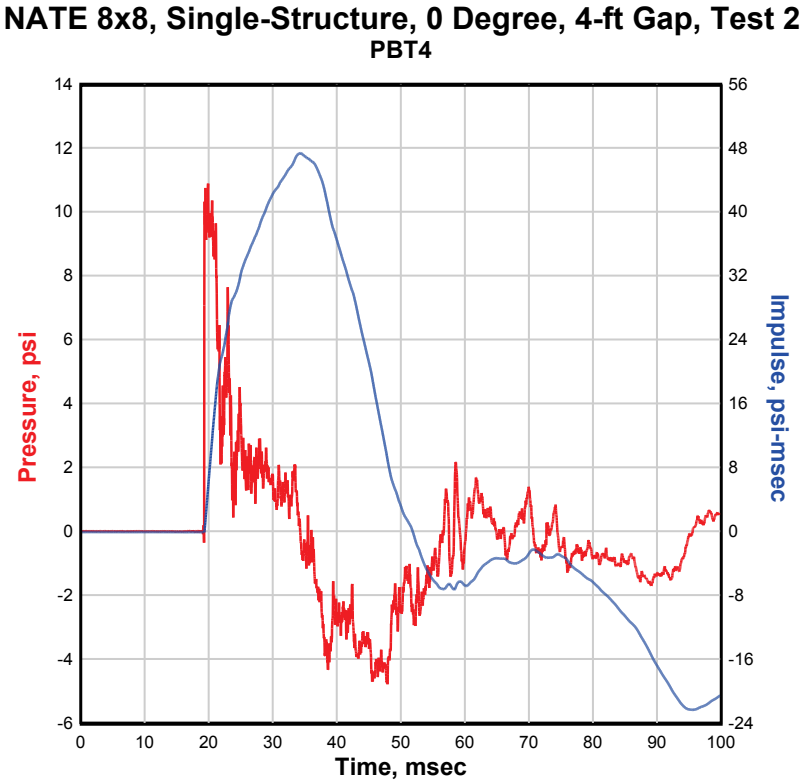

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
150
125
100
75
50
25
0
-25
-50
-75
-100
0
10
20
30
40
50
60
70
80
90
100

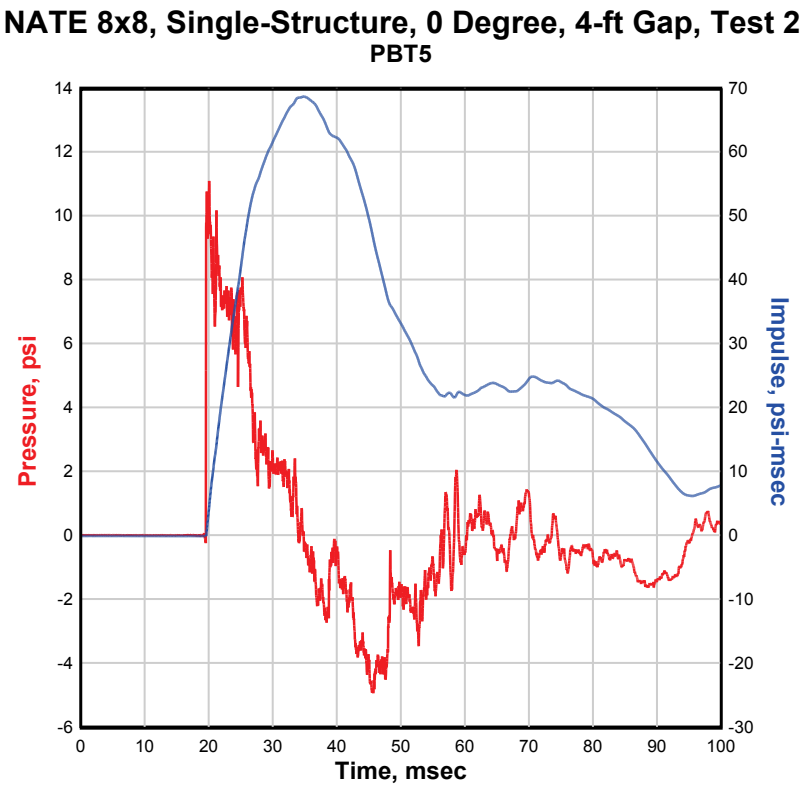

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

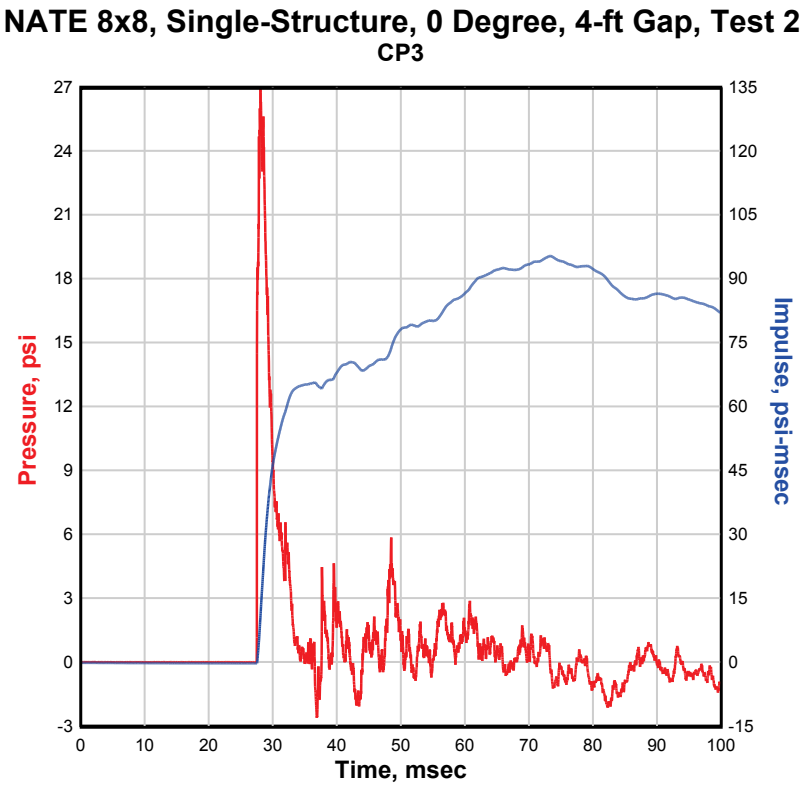

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

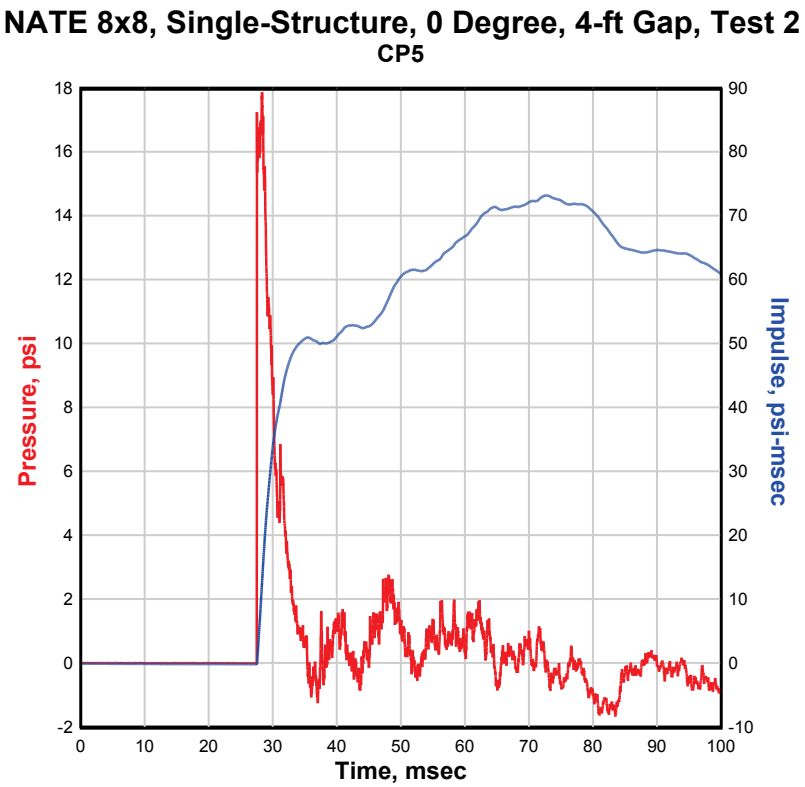

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

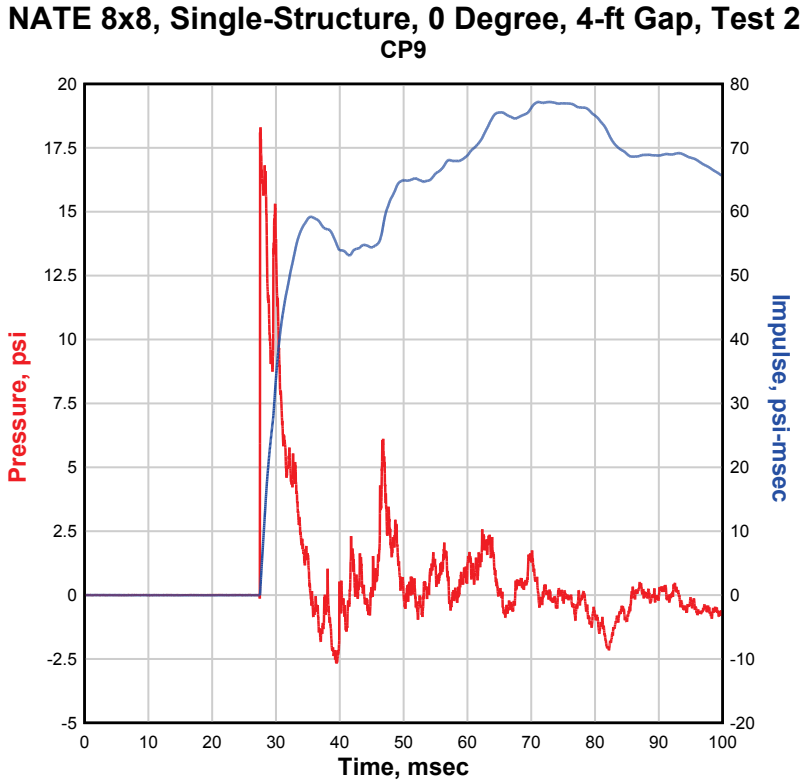

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

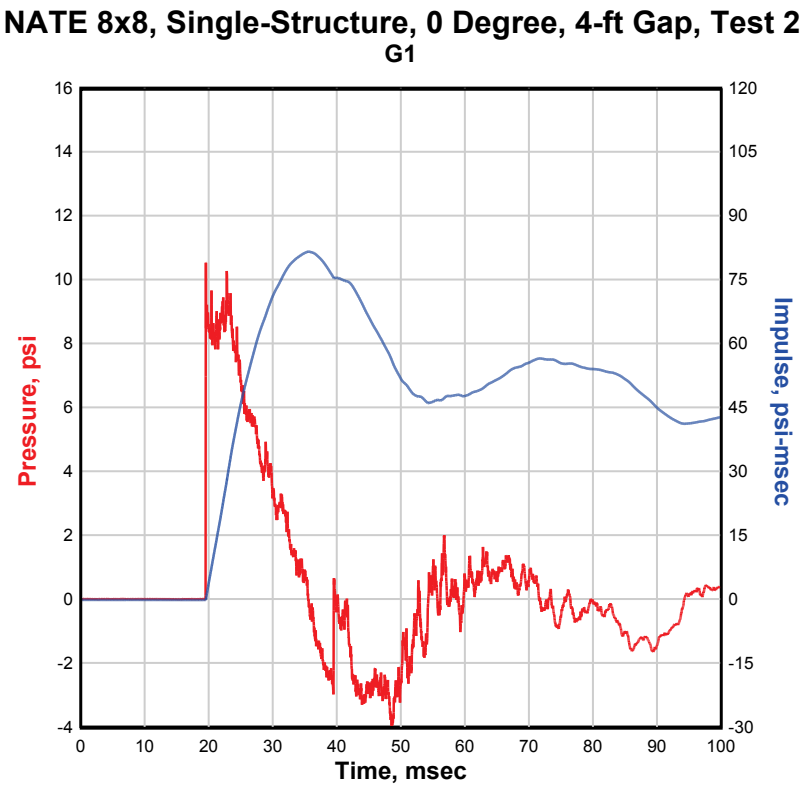

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

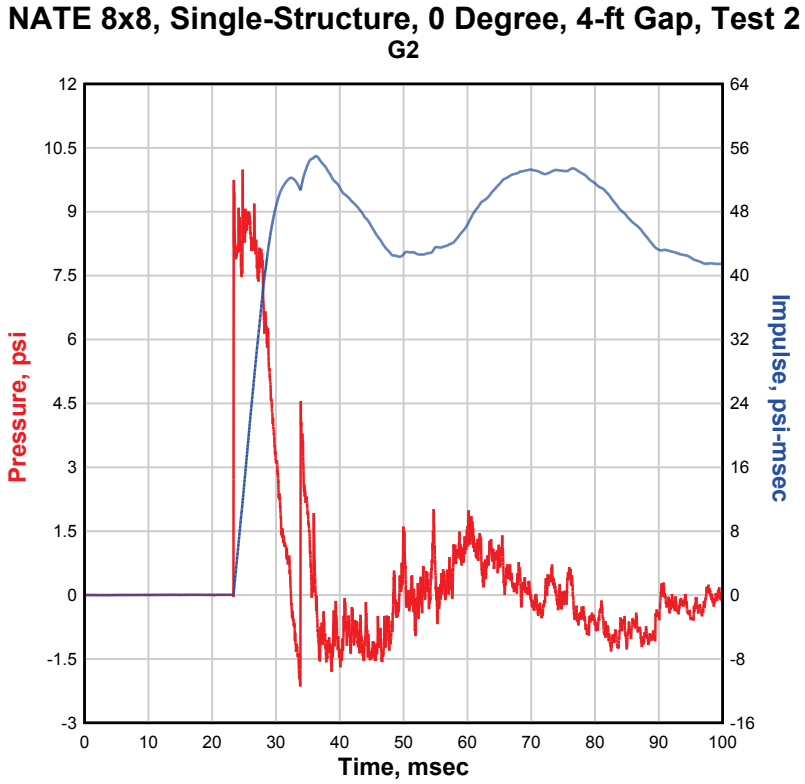

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

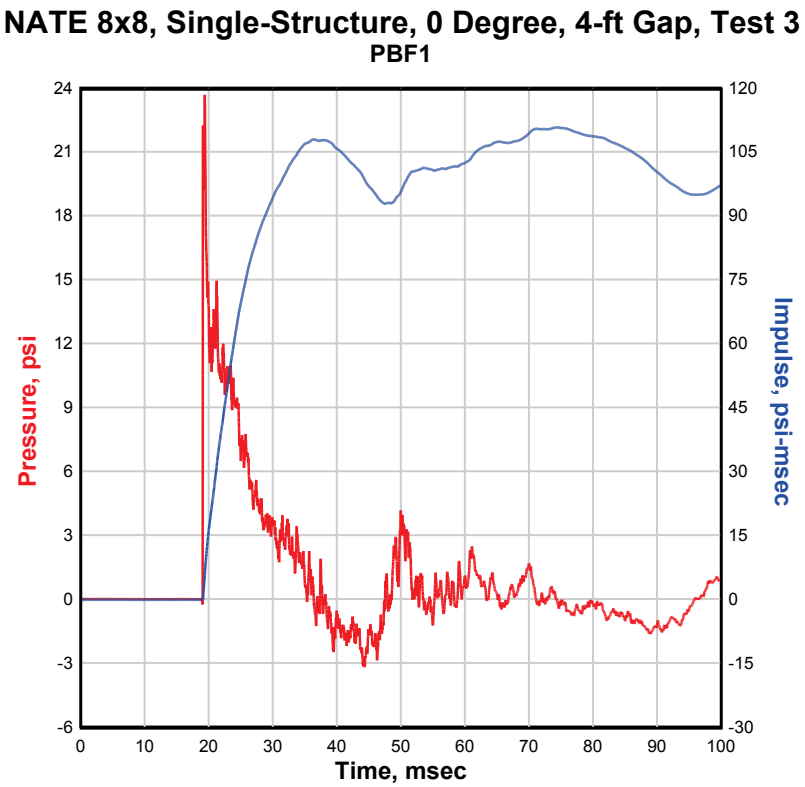

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

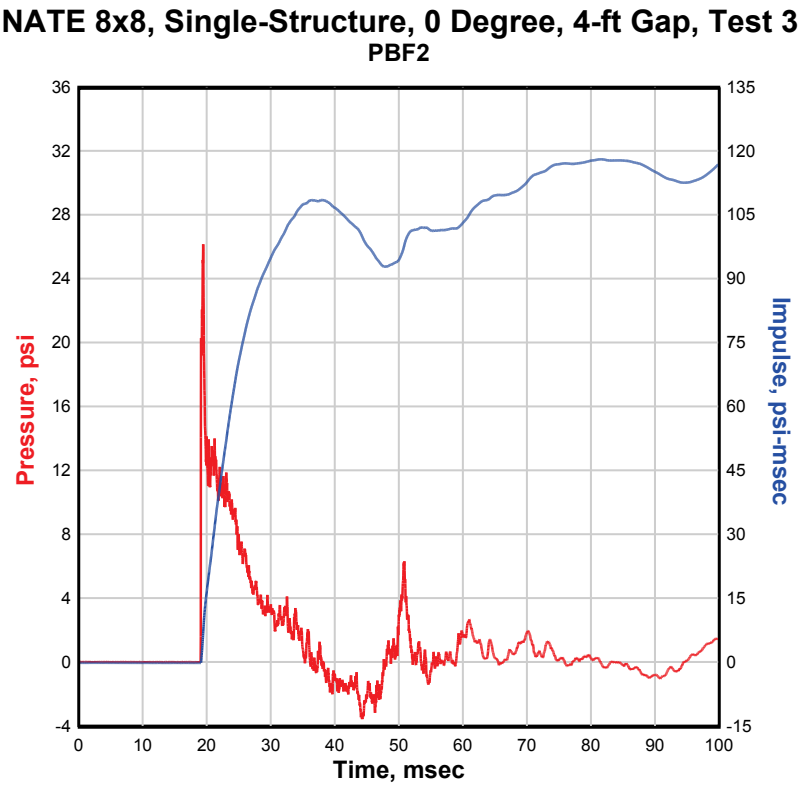

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
18
16
14
12
10
8
6
4
2
0
-2
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

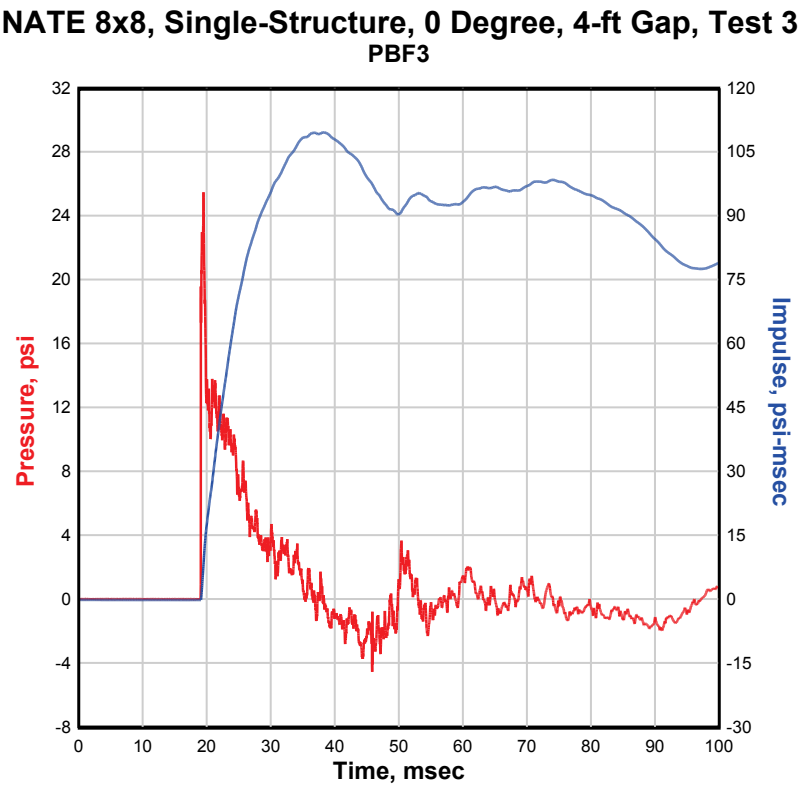

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
80
70
60
50
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100

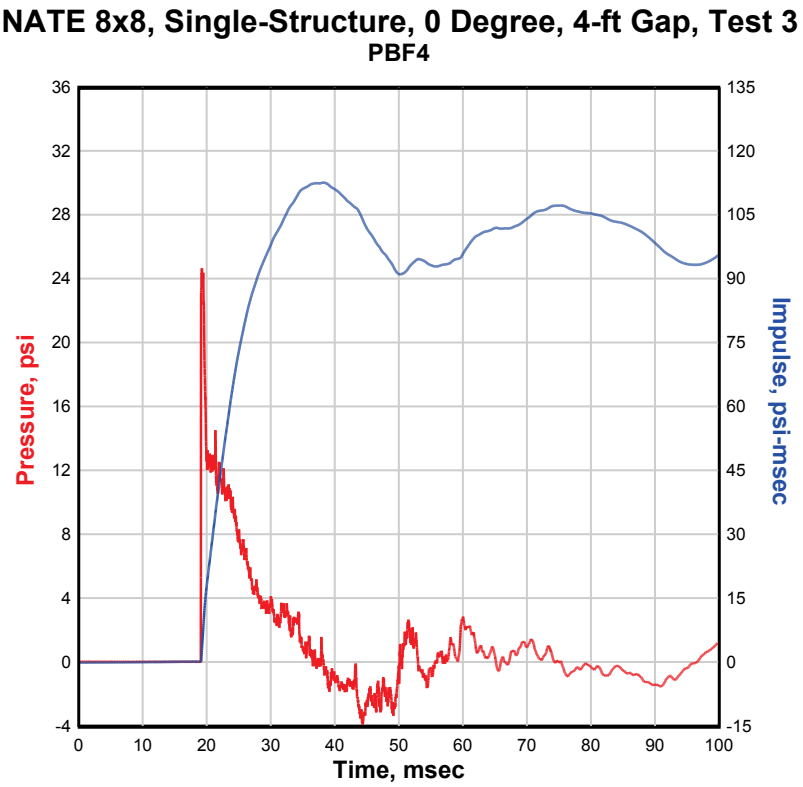

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
G1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

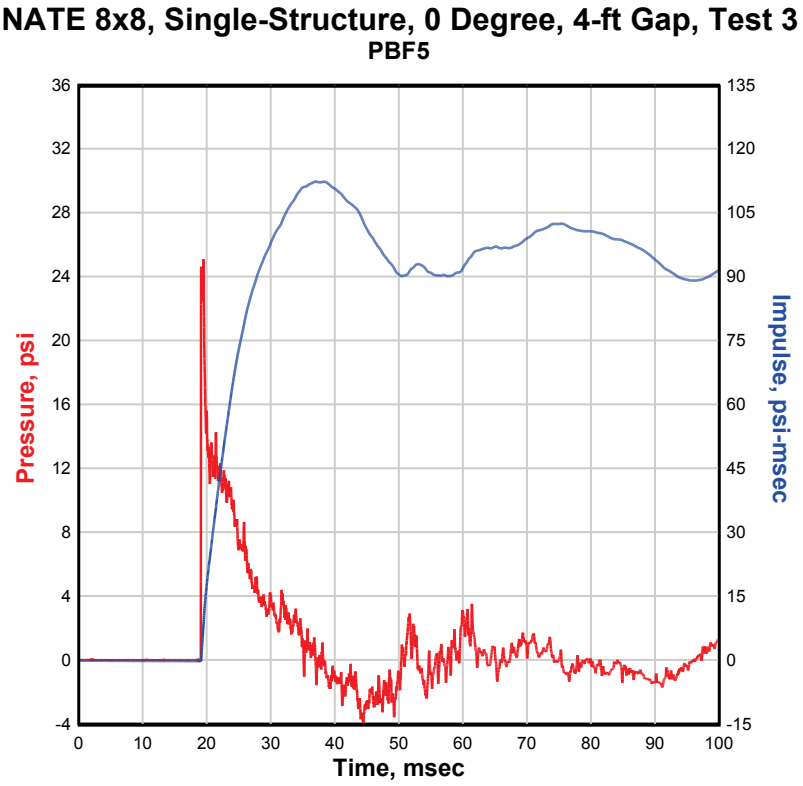

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 2
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

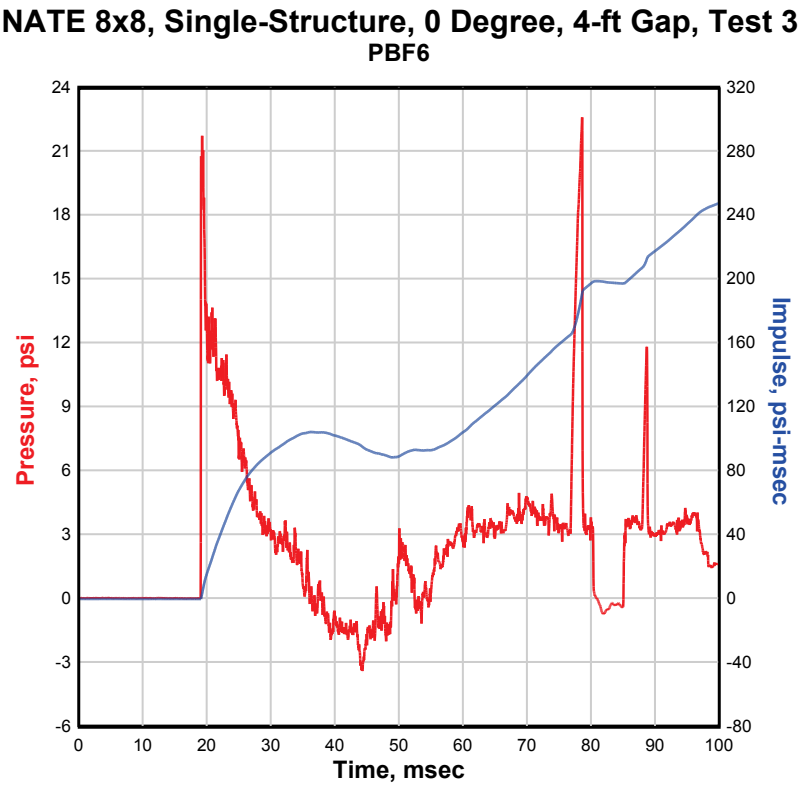

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

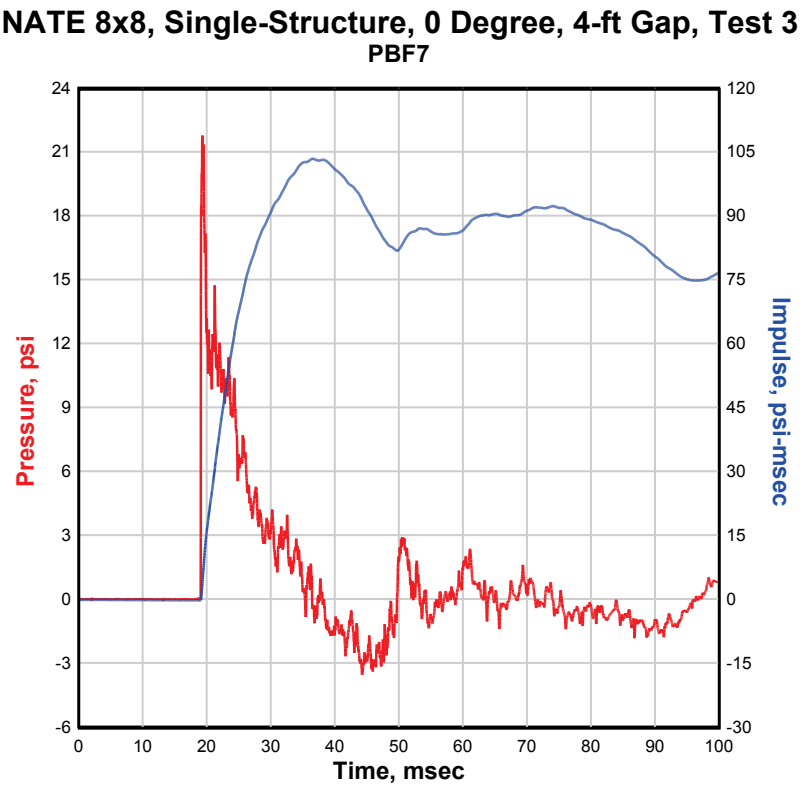

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

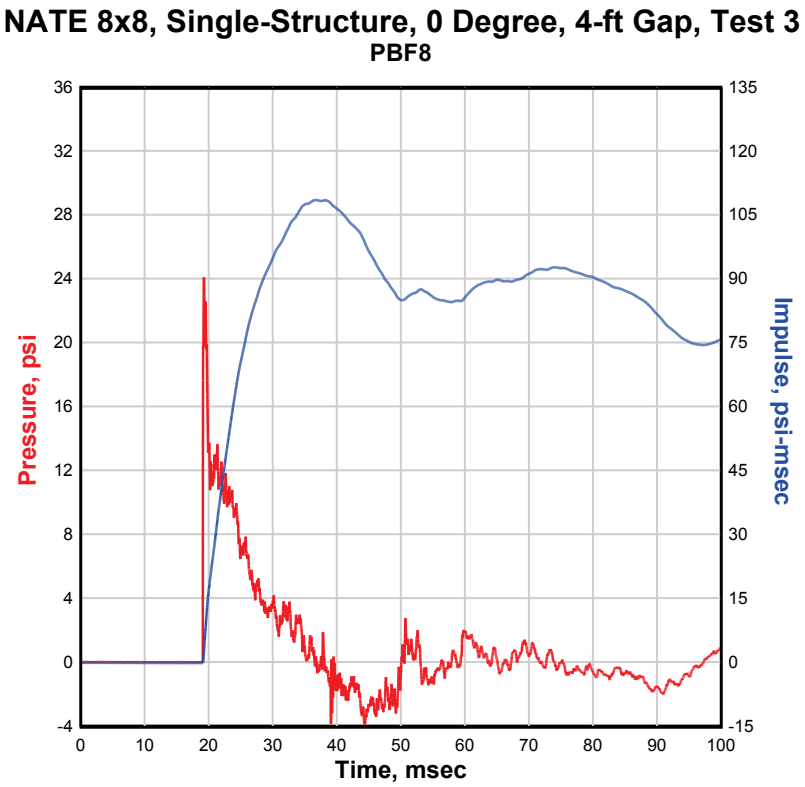

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

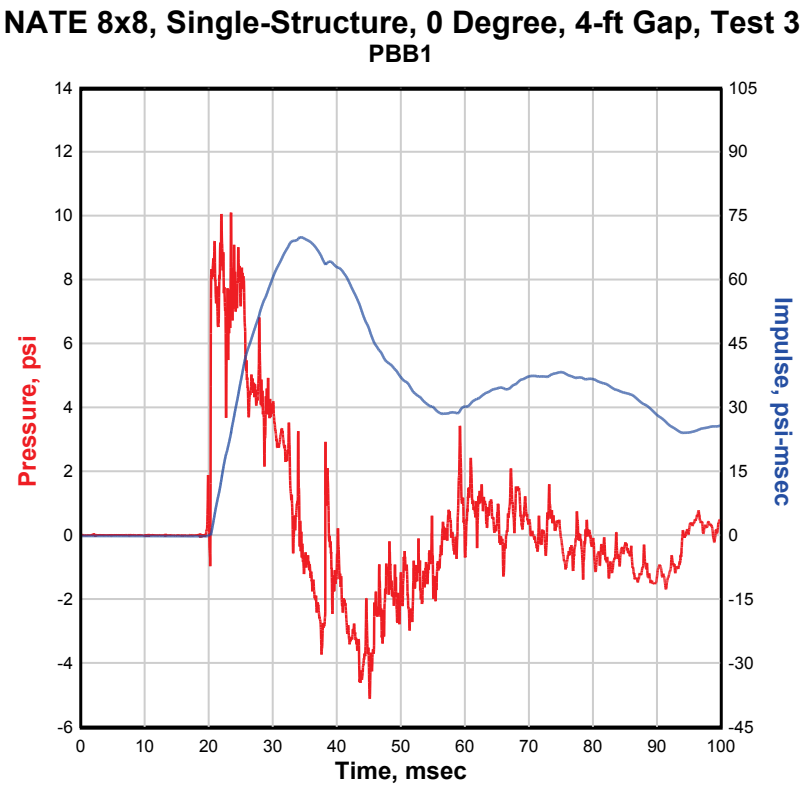

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

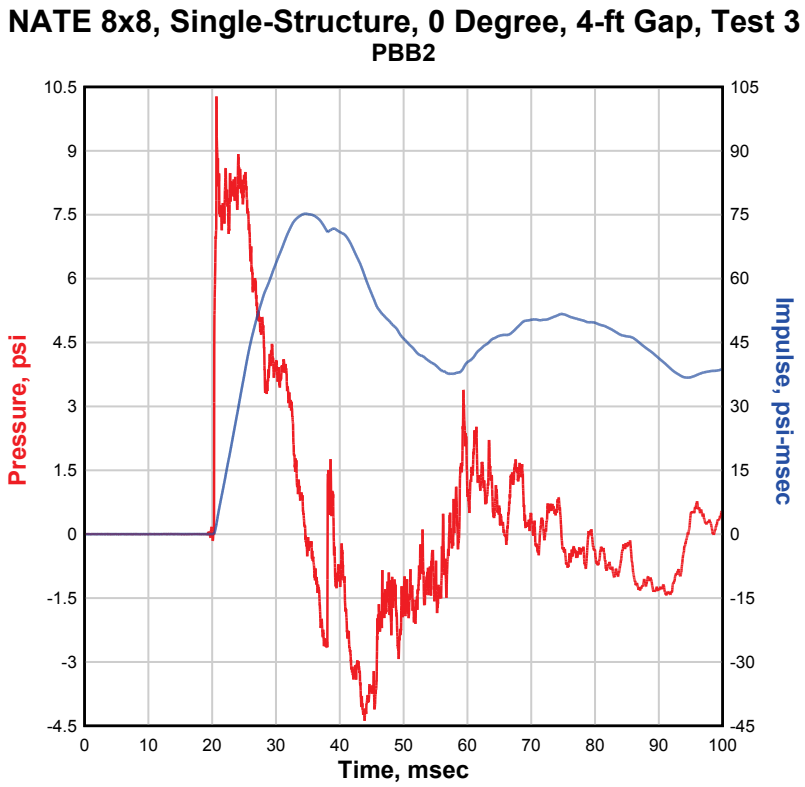

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

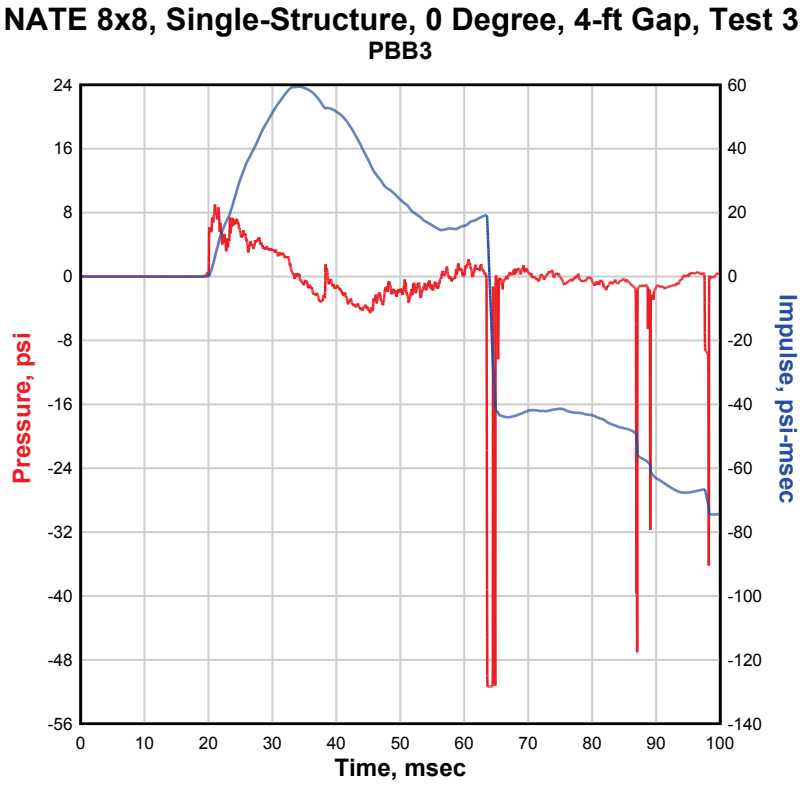

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
320
280
240
200
160
120
80
40
0
-40
-80
0
10
20
30
40
50
60
70
80
90
100

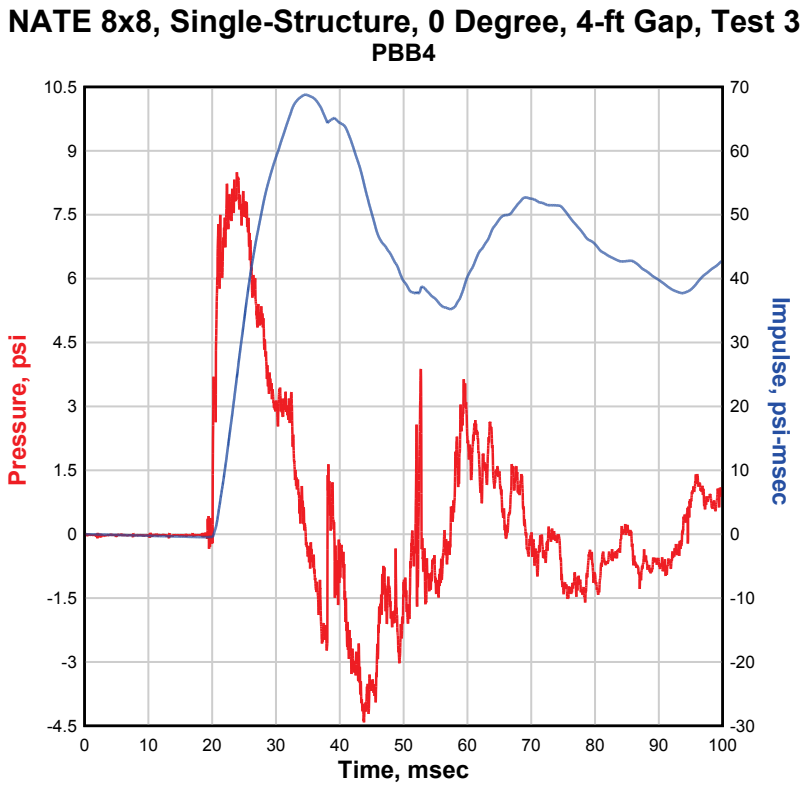

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

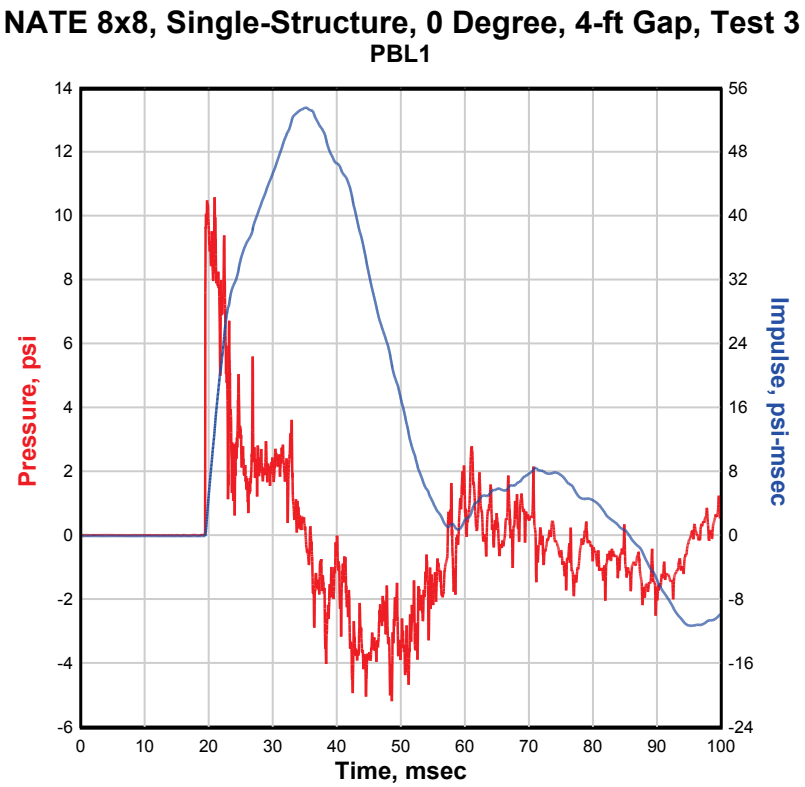

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

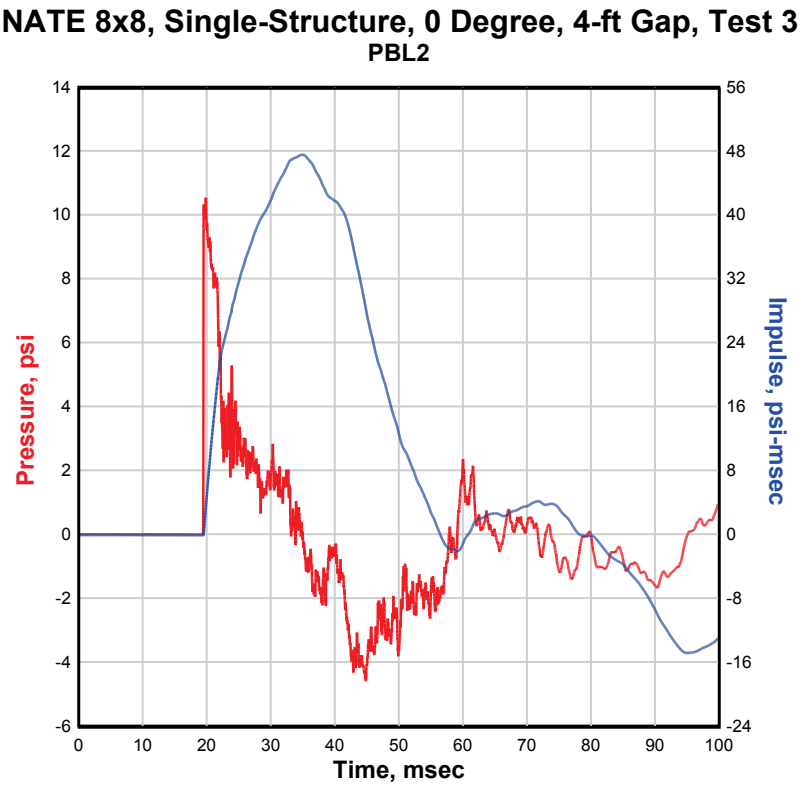

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

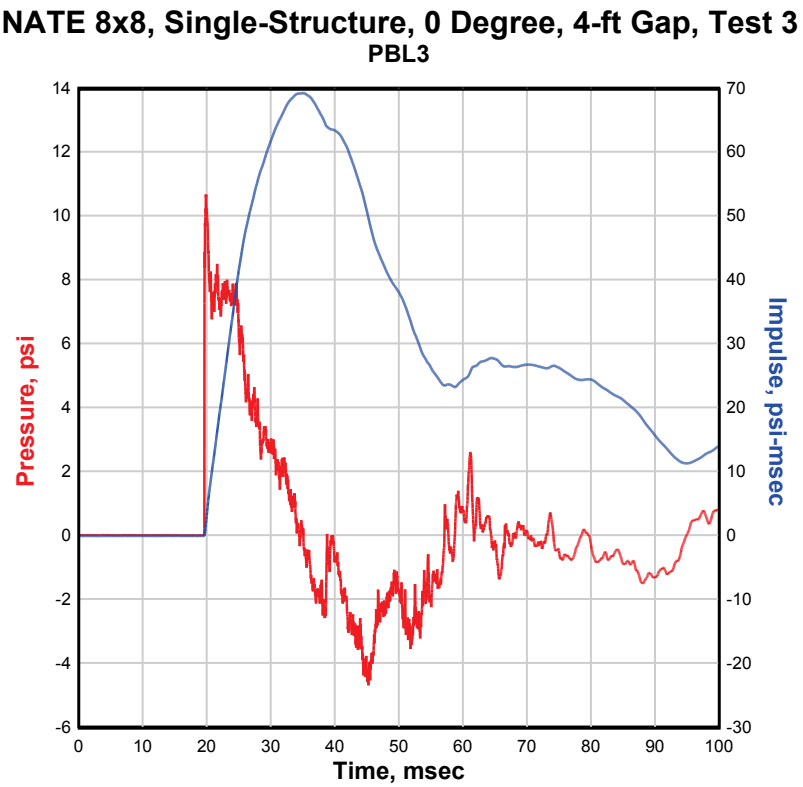

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
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0
-10
-20
-30
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10
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30
40
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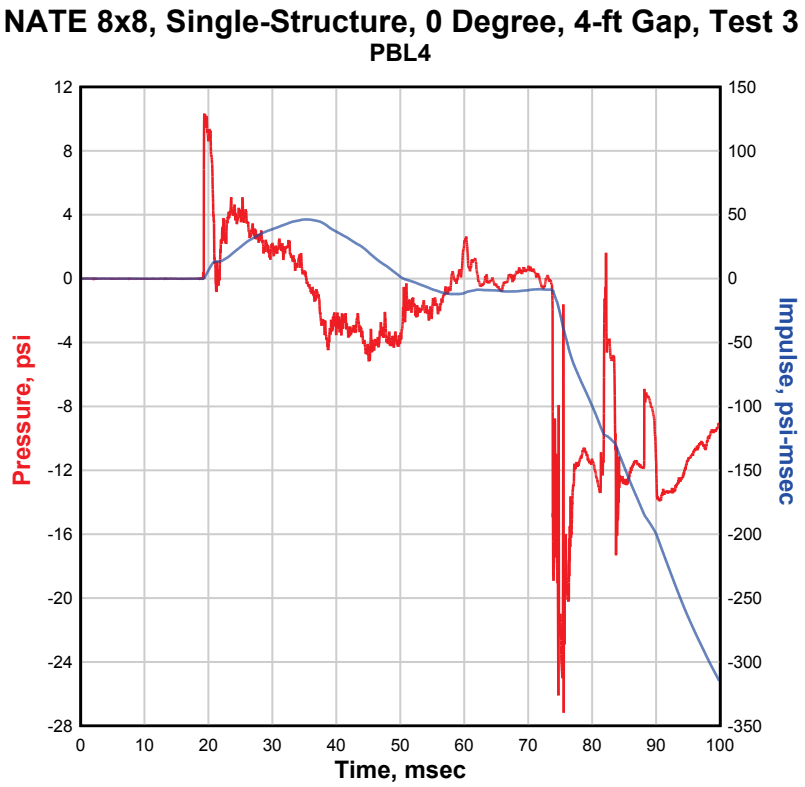
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
12
8
4
0
-4
-8
-12
-16
-20
-24
-28
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
0
10
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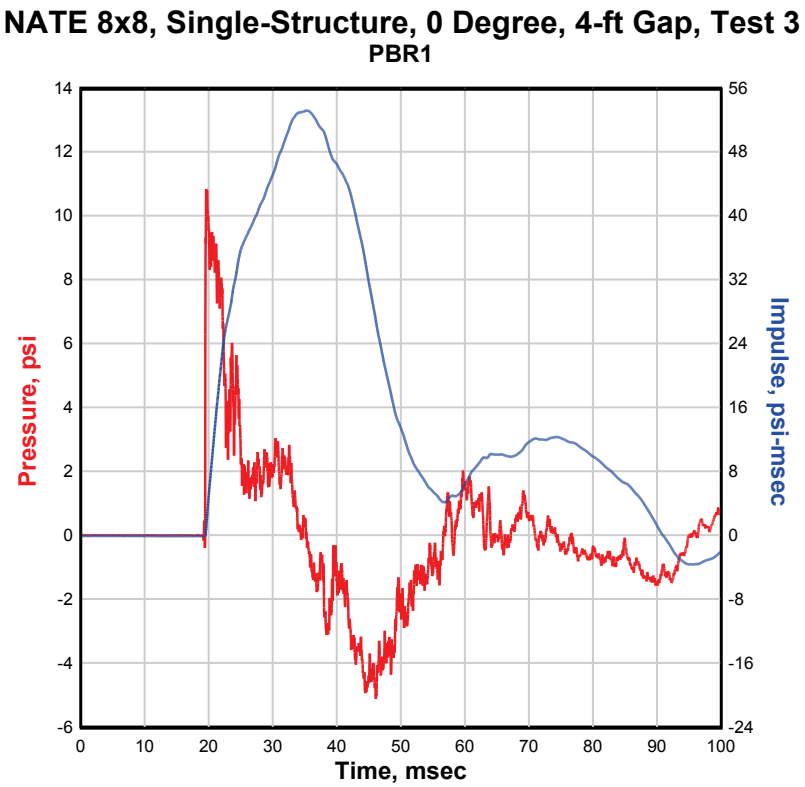
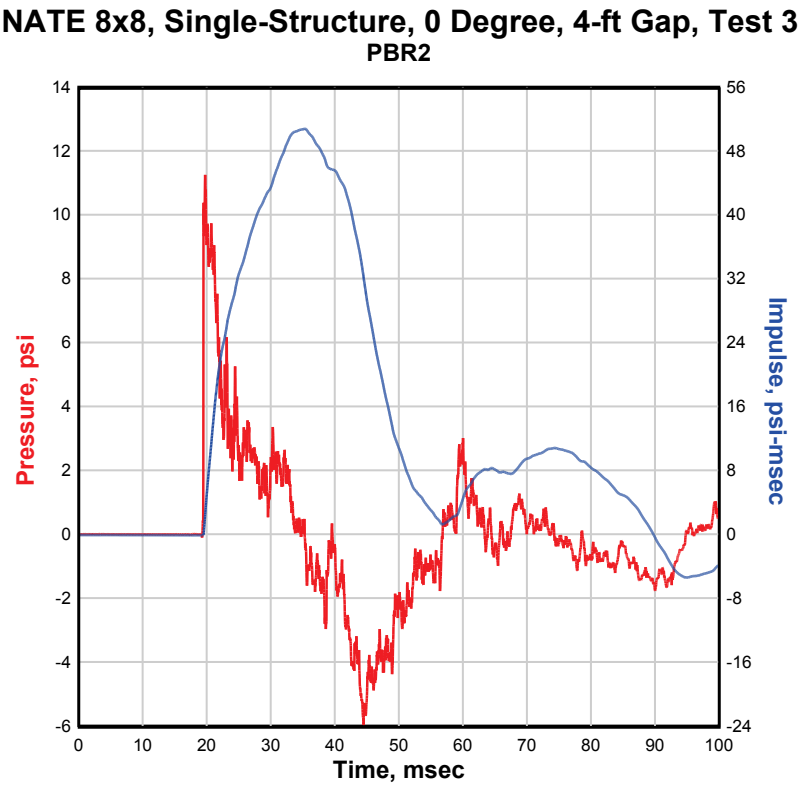
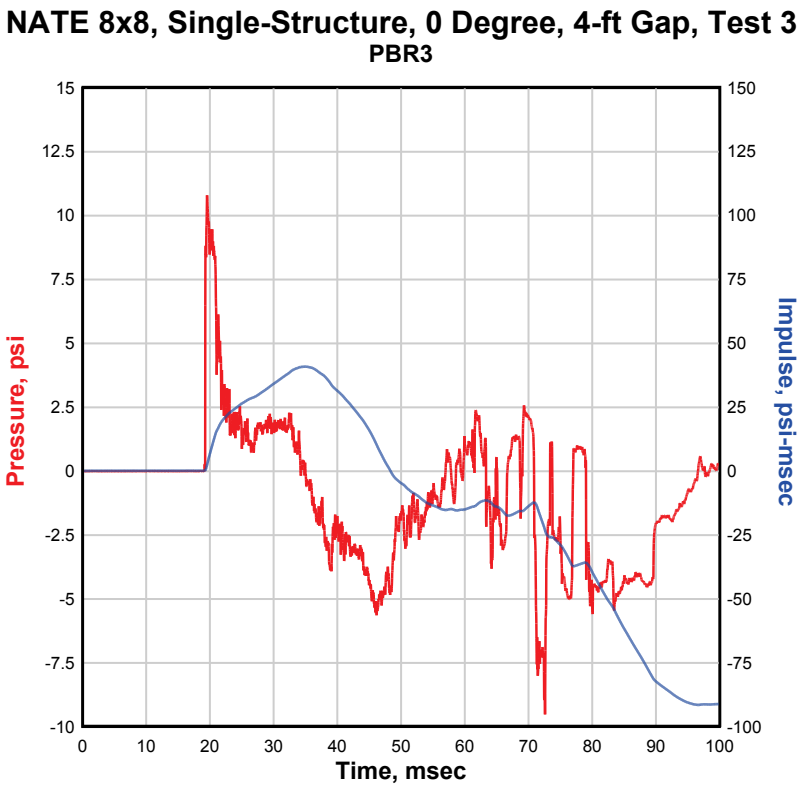
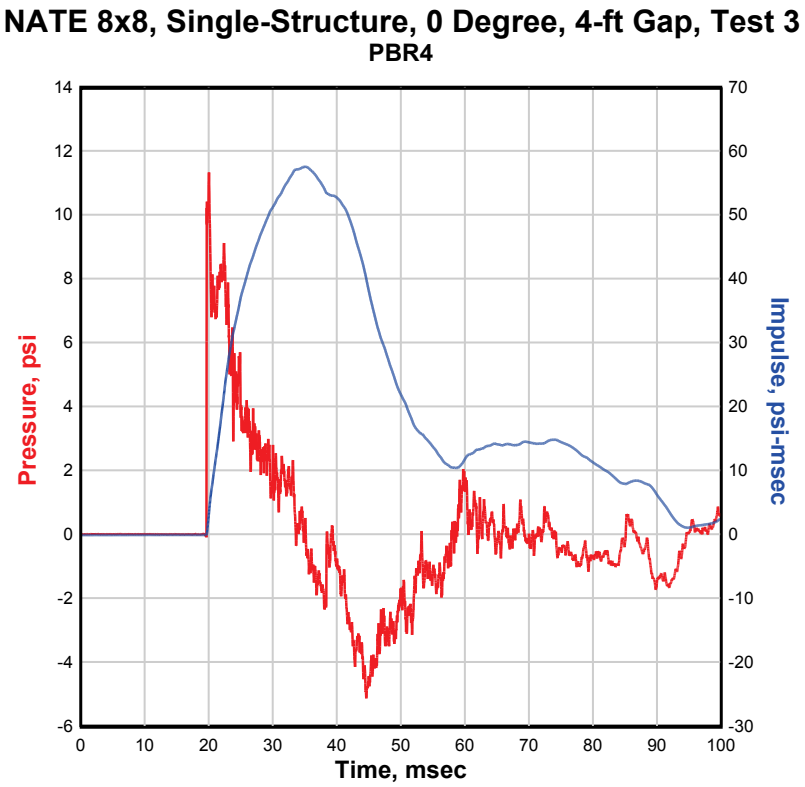
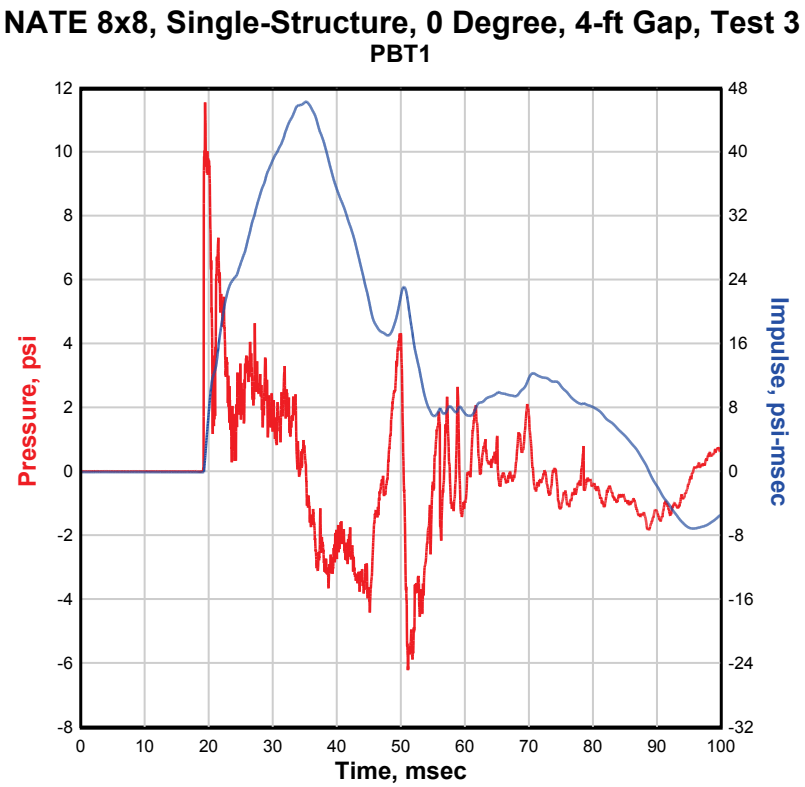
30
40
50
60
70
80
90
100

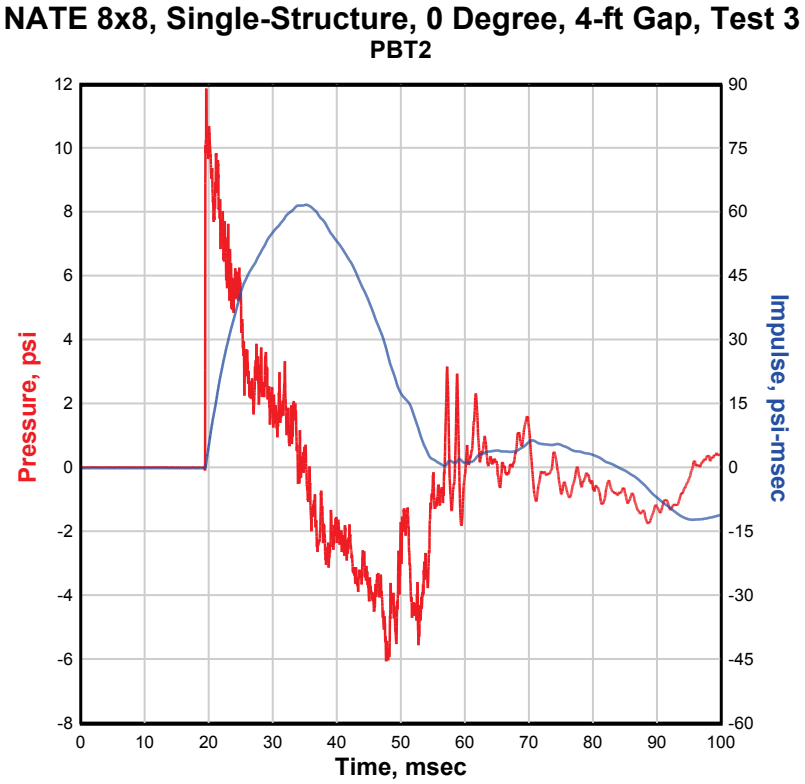

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

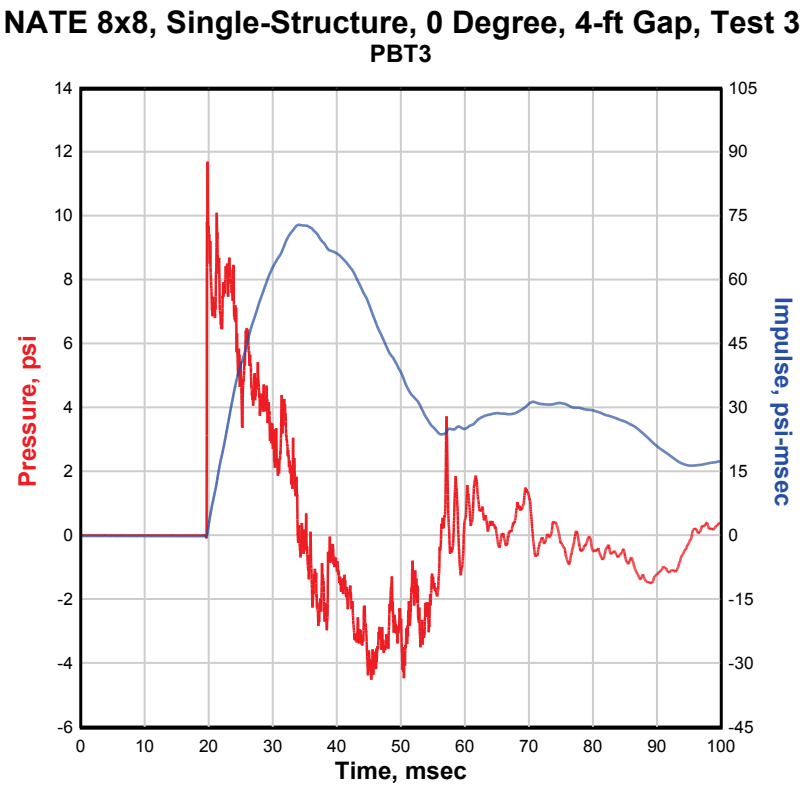

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

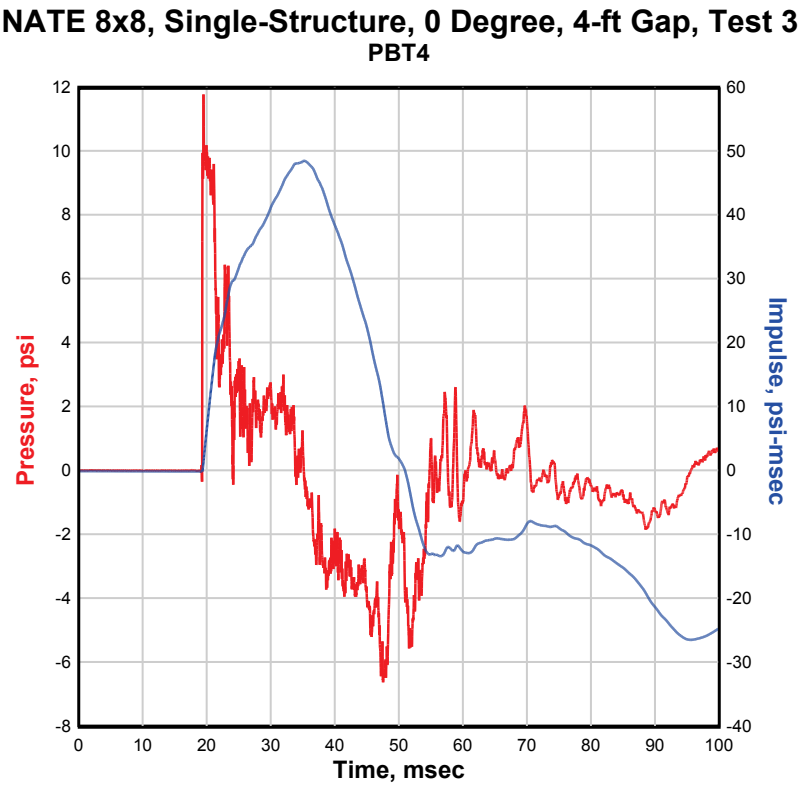

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
15
12.5
10
7.5
5
2.5
0
-2.5
-5
-7.5
-10
150
125
100
75
50
25
0
-25
-50
-75
-100
0
10
20
30
40
50
60
70
80
90
100

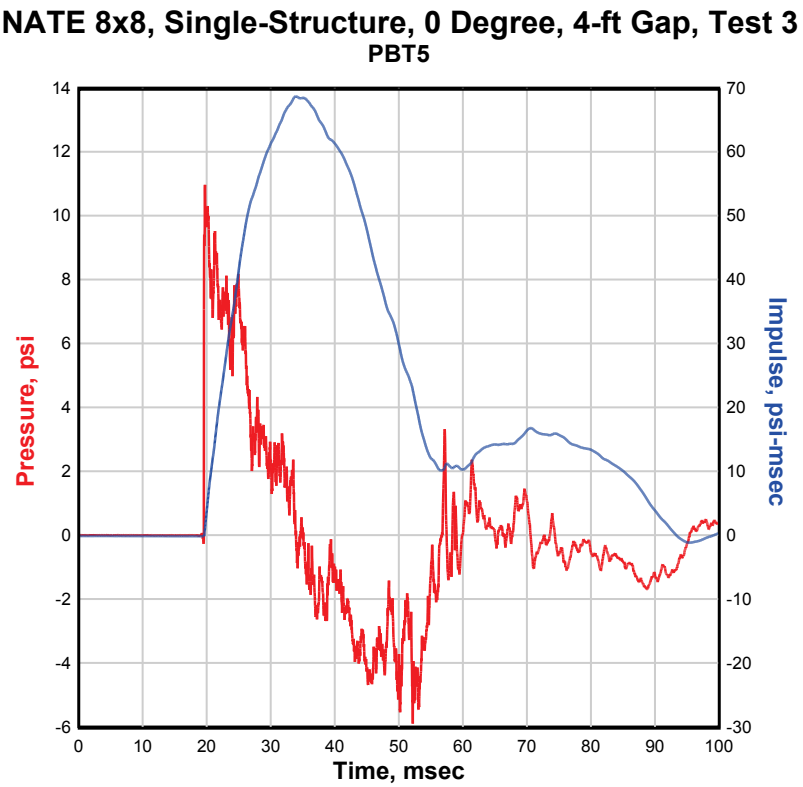

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

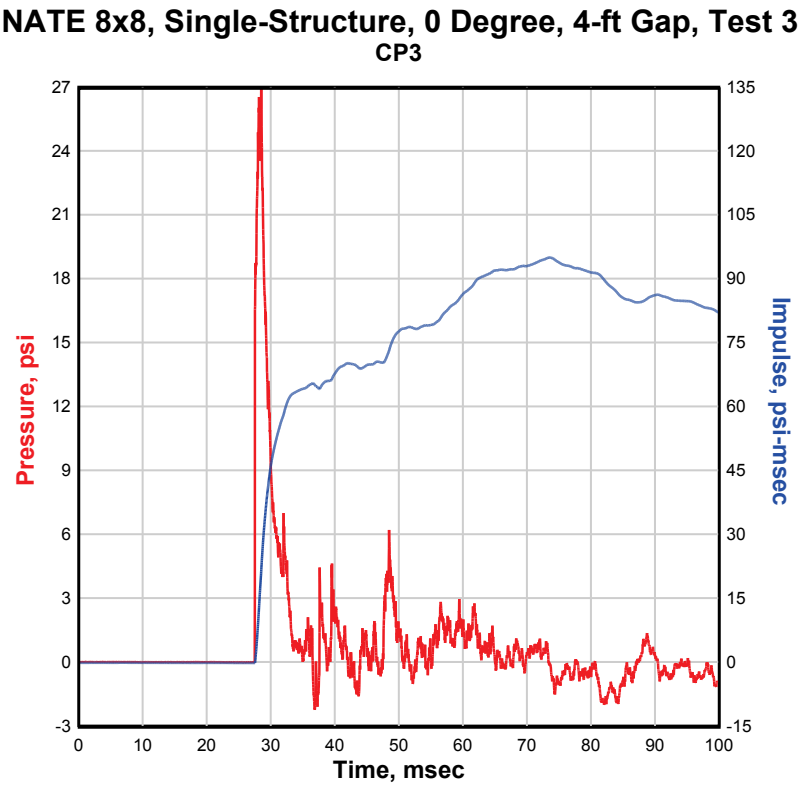

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100

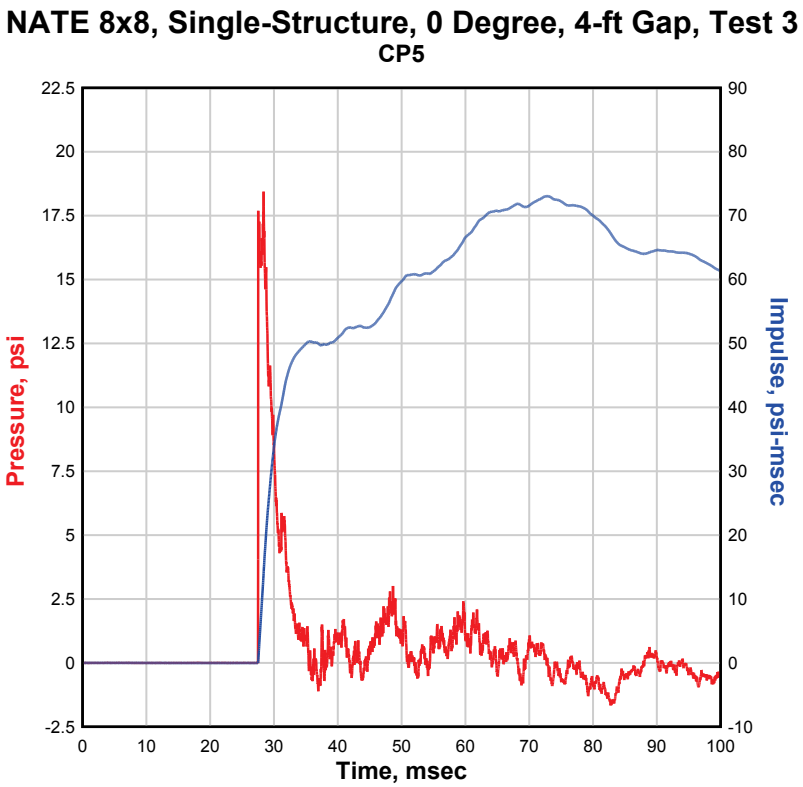

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

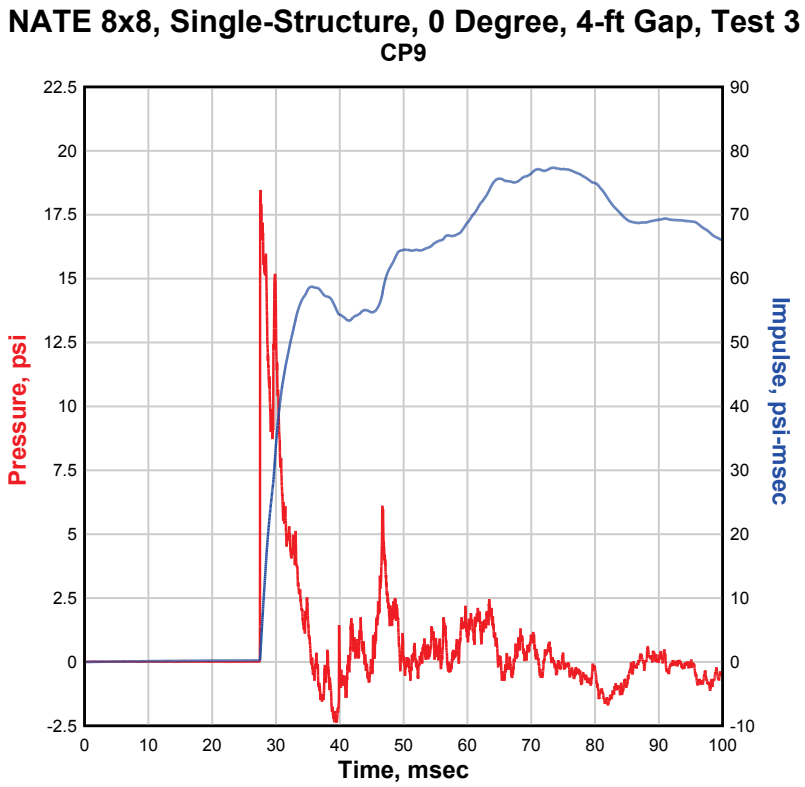

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

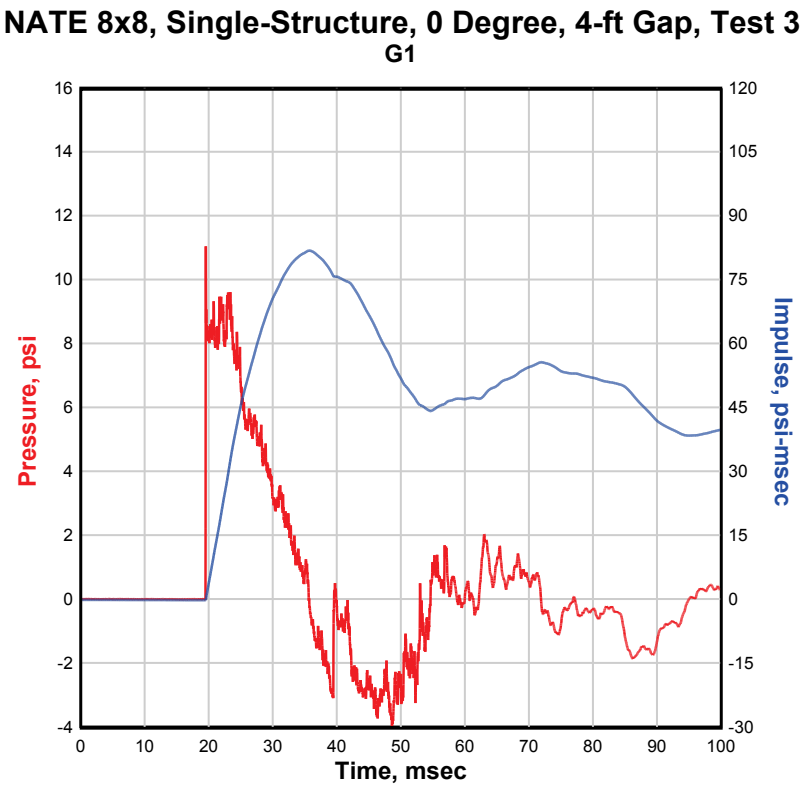

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100

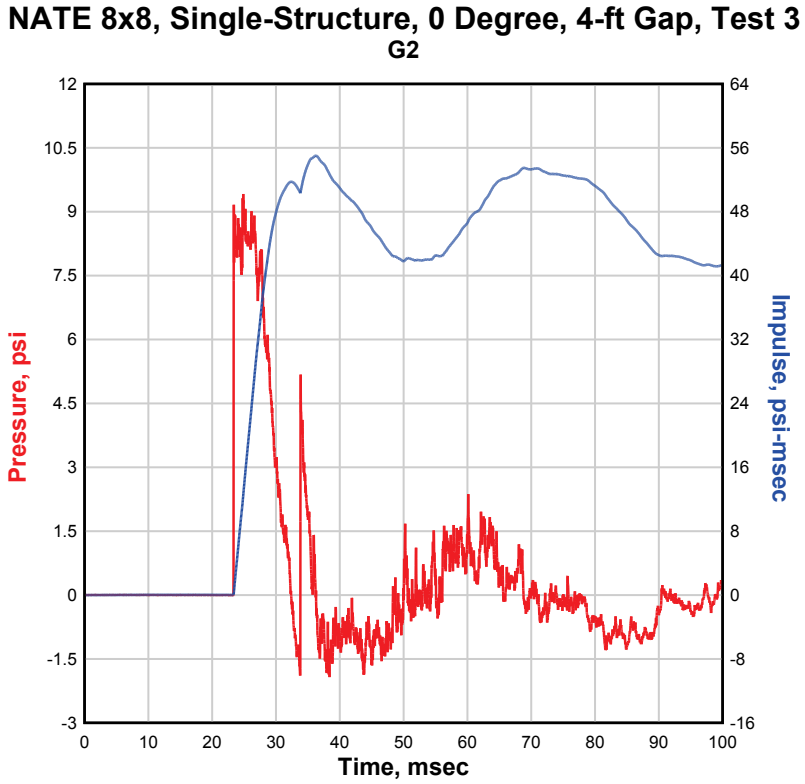

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

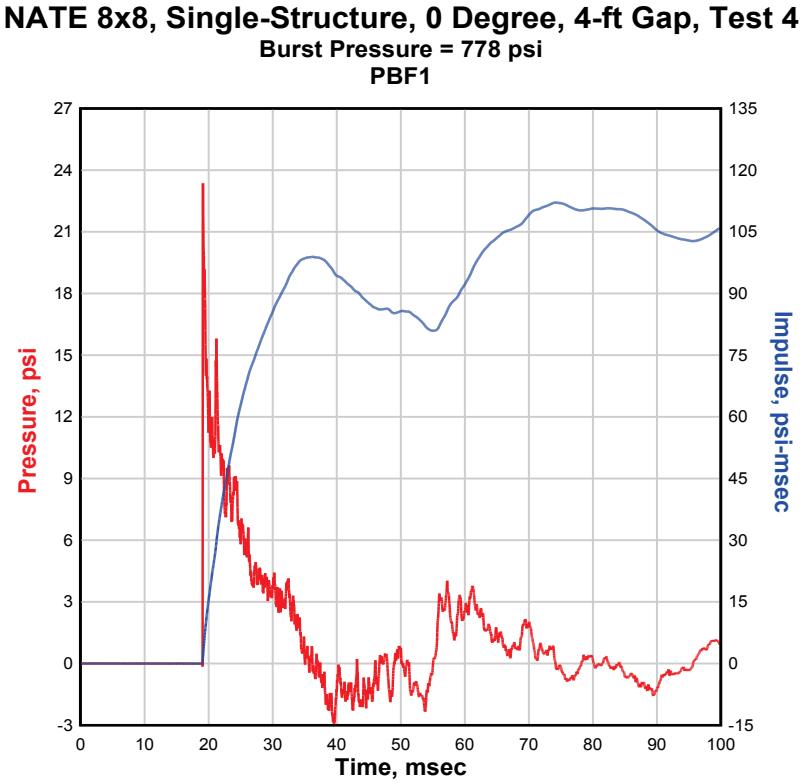

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

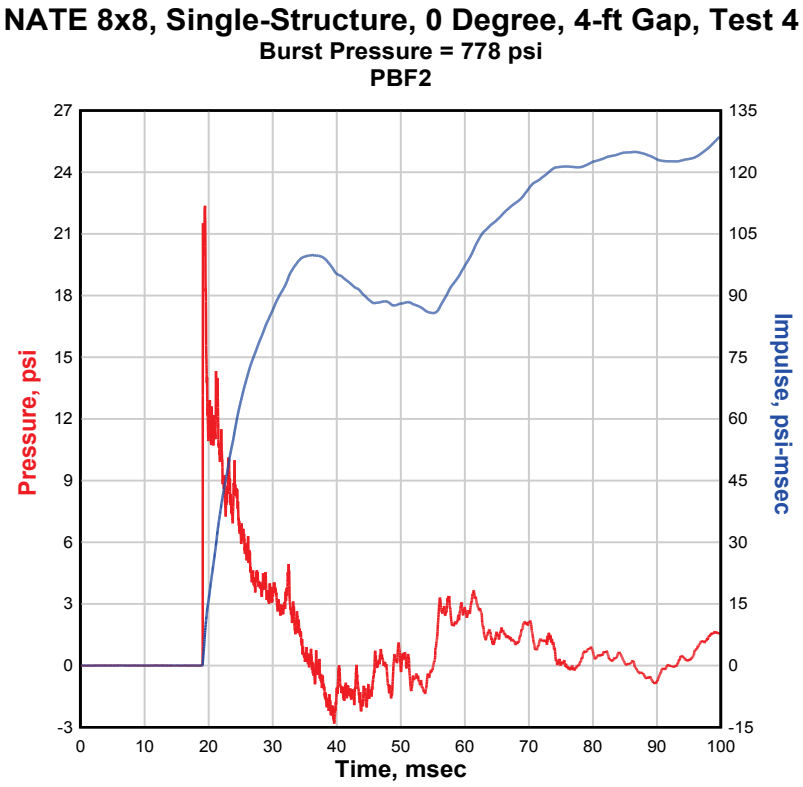

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

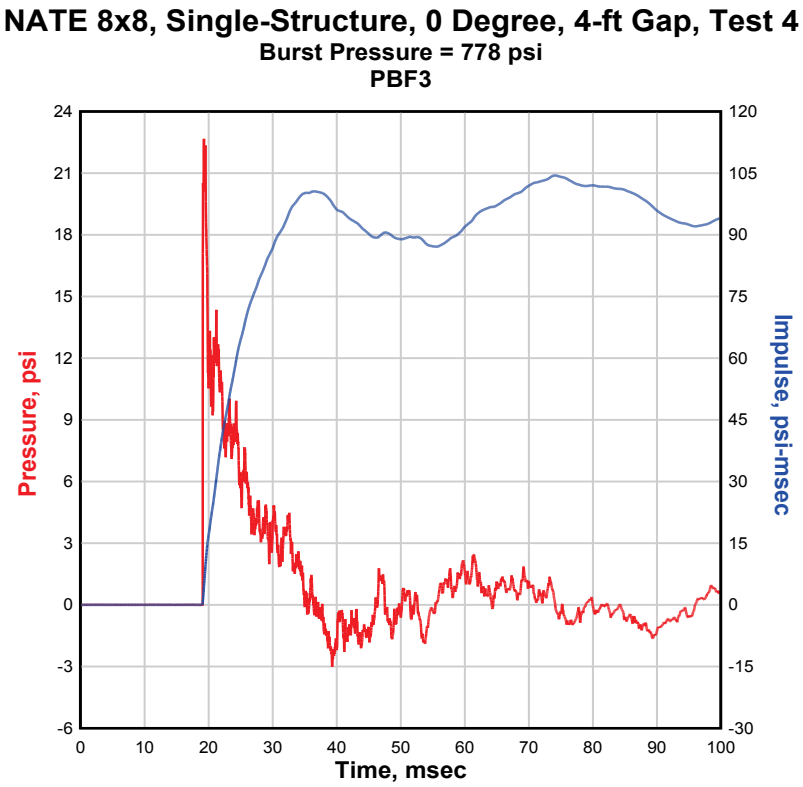

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

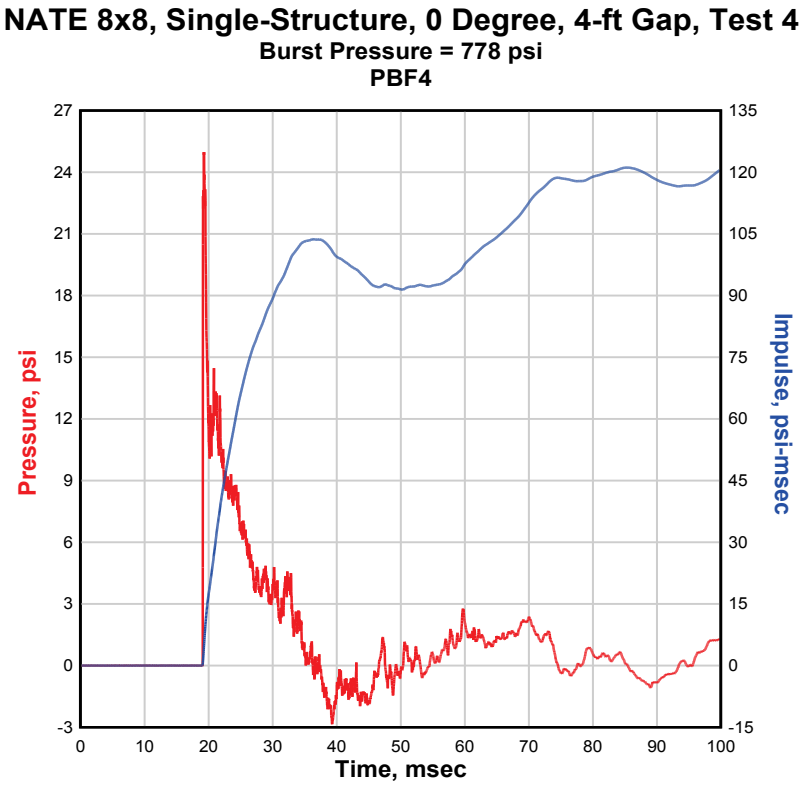

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
G1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

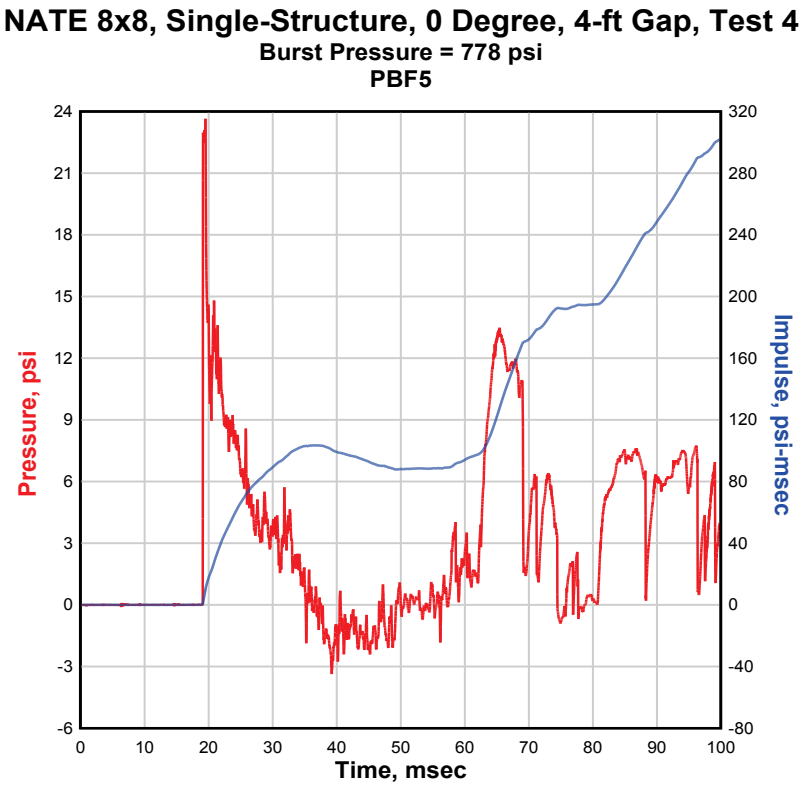

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 3
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

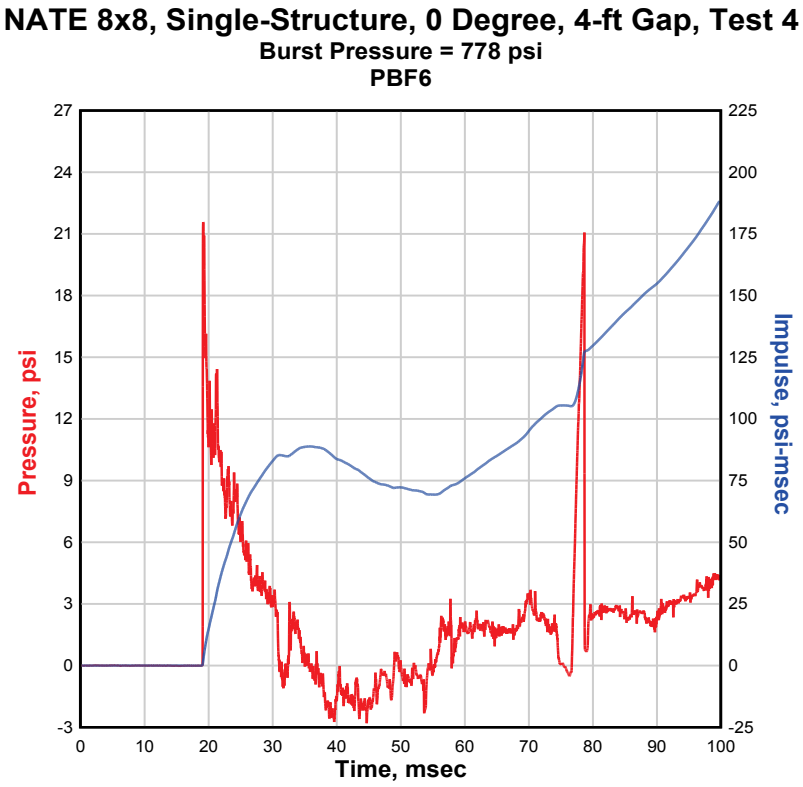

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

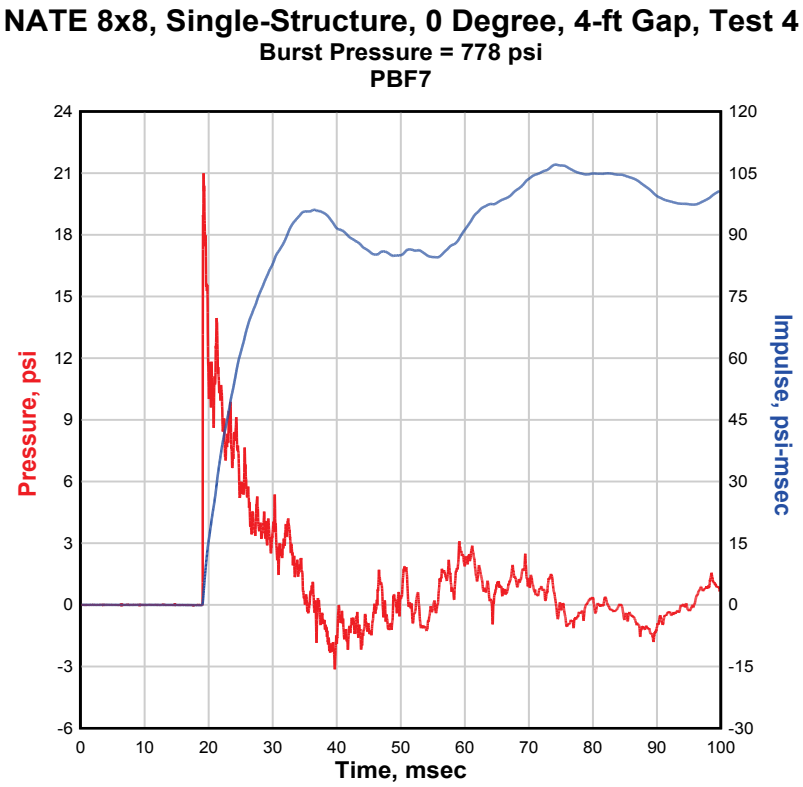

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

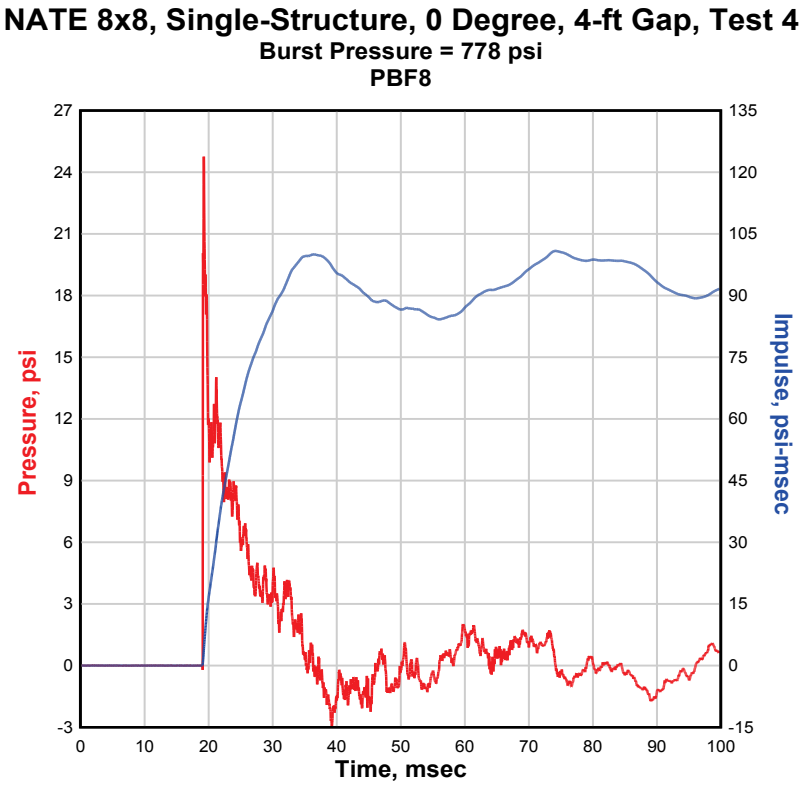

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

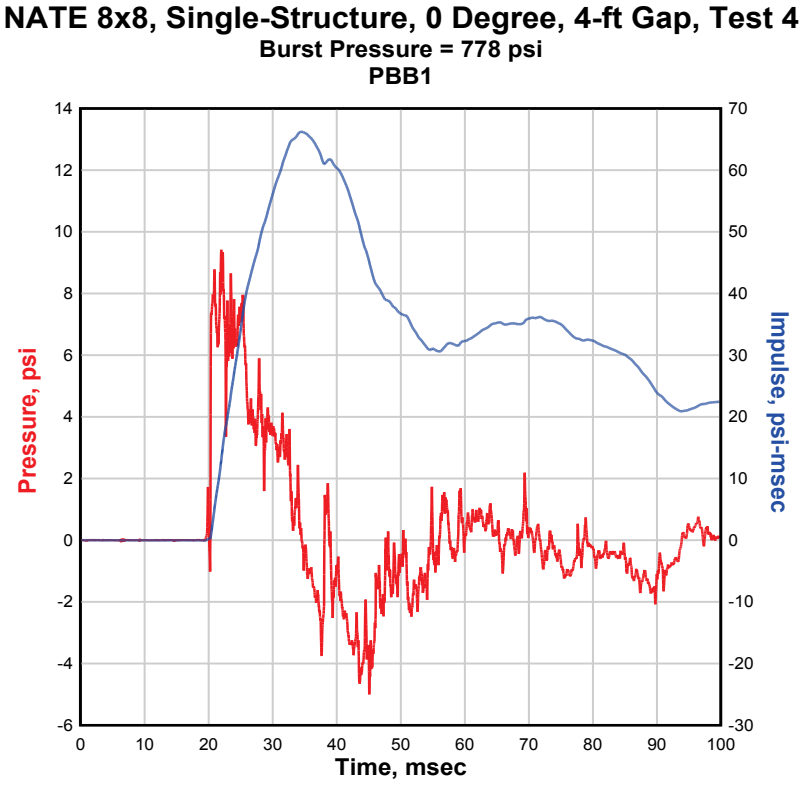

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

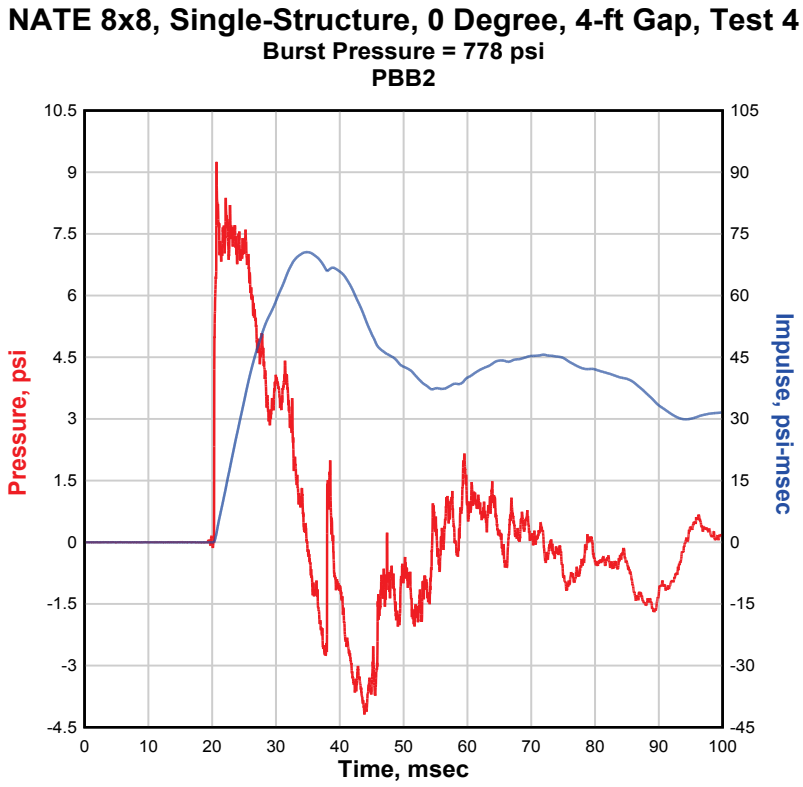

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
320
280
240
200
160
120
80
40
0
-40
-80
0
10
20
30
40
50
60
70
80
90
100

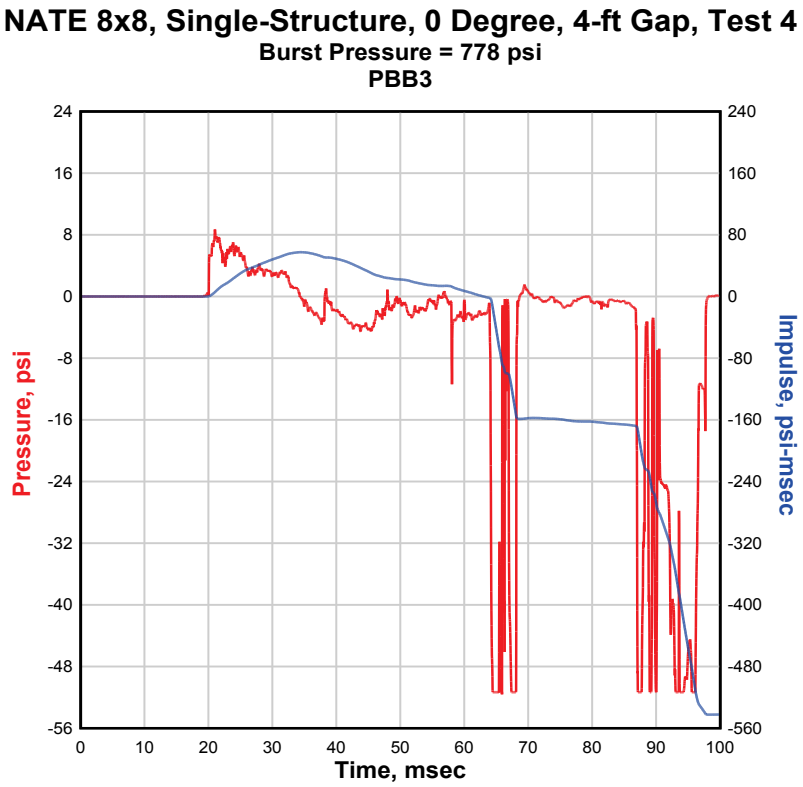

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
225
200
175
150
125
100
75
50
25
0
-25
0
10
20
30
40
50
60
70
80
90
100

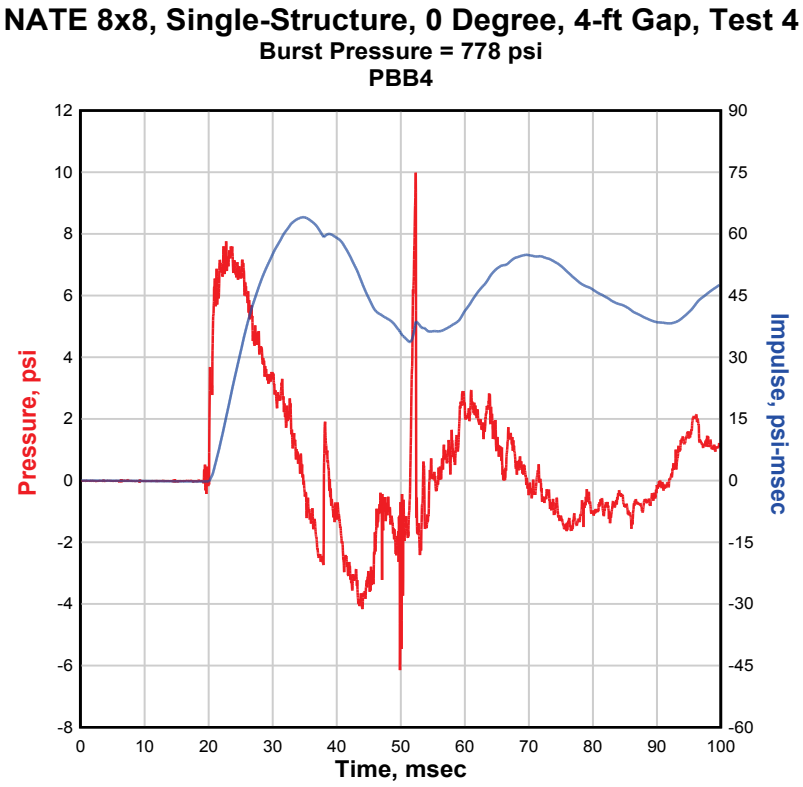

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

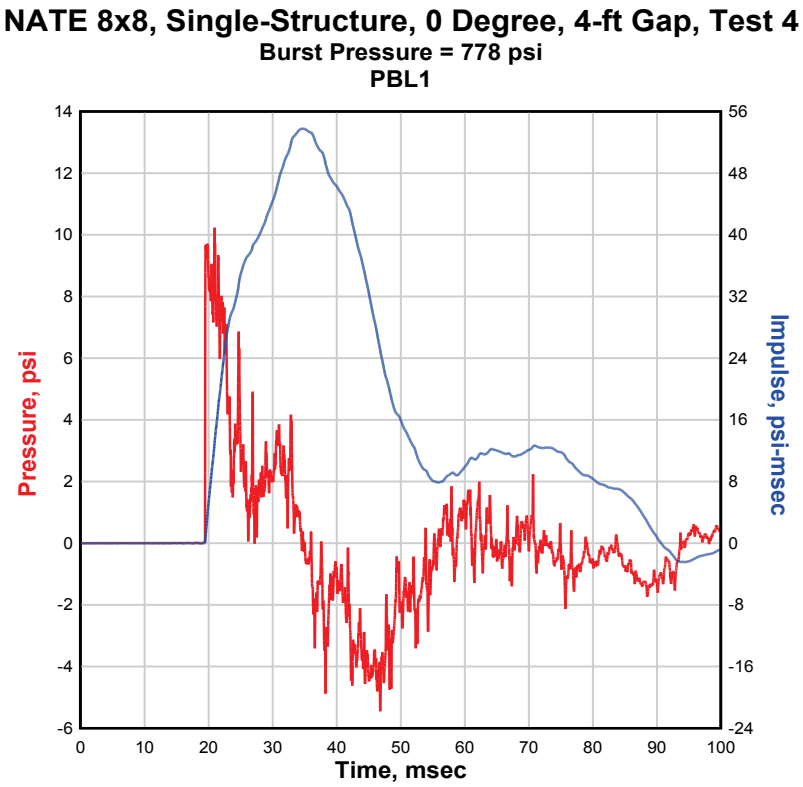

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

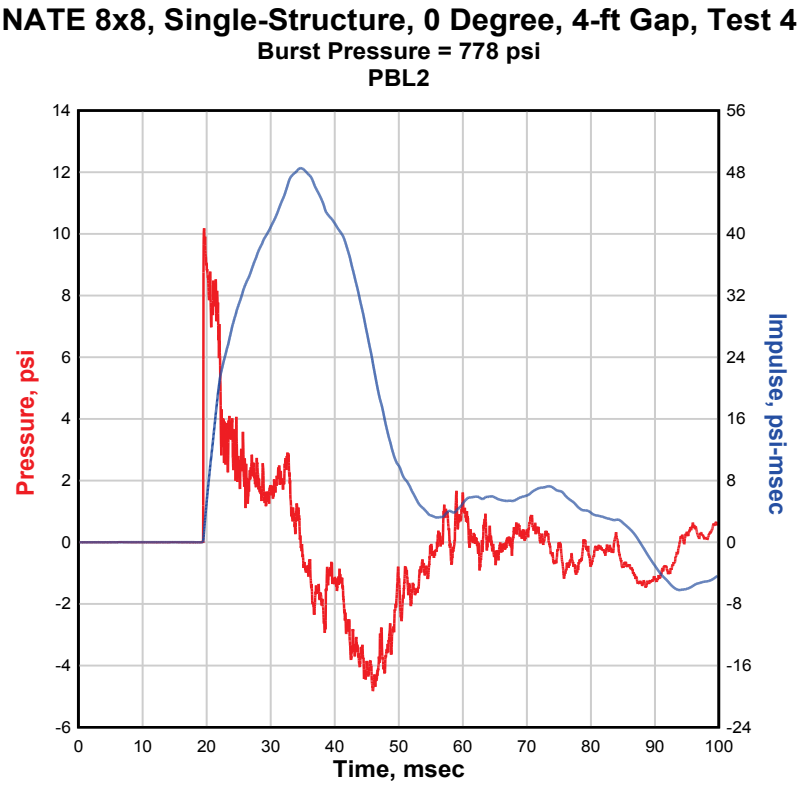

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

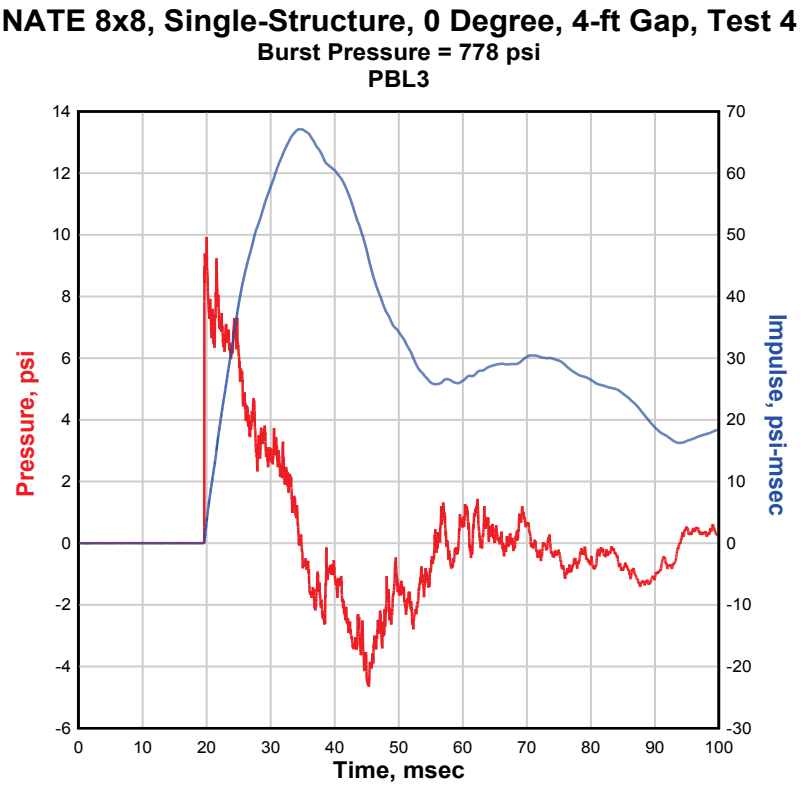

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

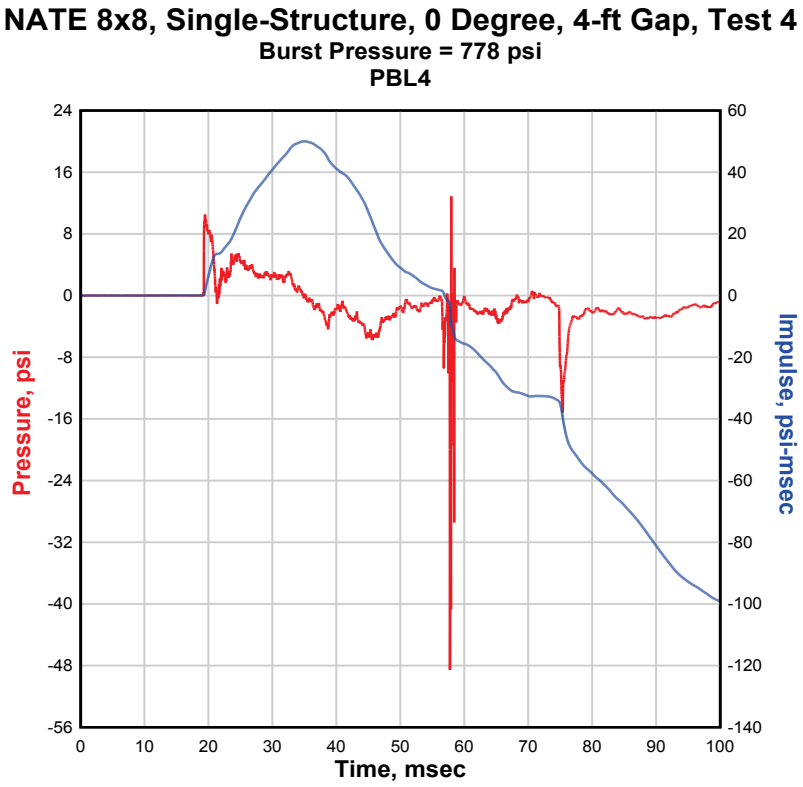

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
240
160
80
0
-80
-160
-240
-320
-400
-480
-560
0
10
20
30
40
50
60
70
80
90
100

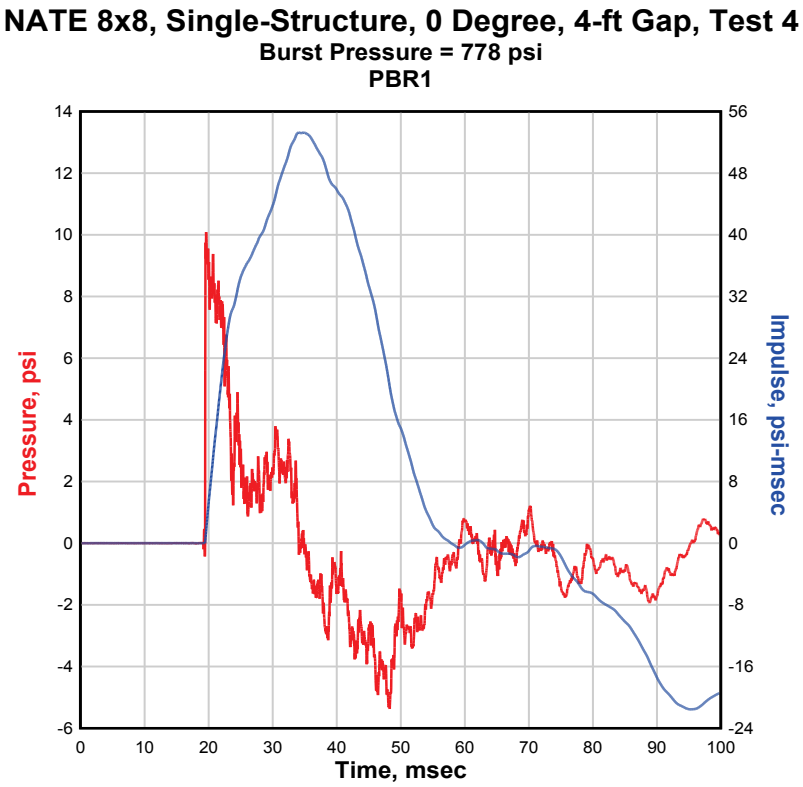

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

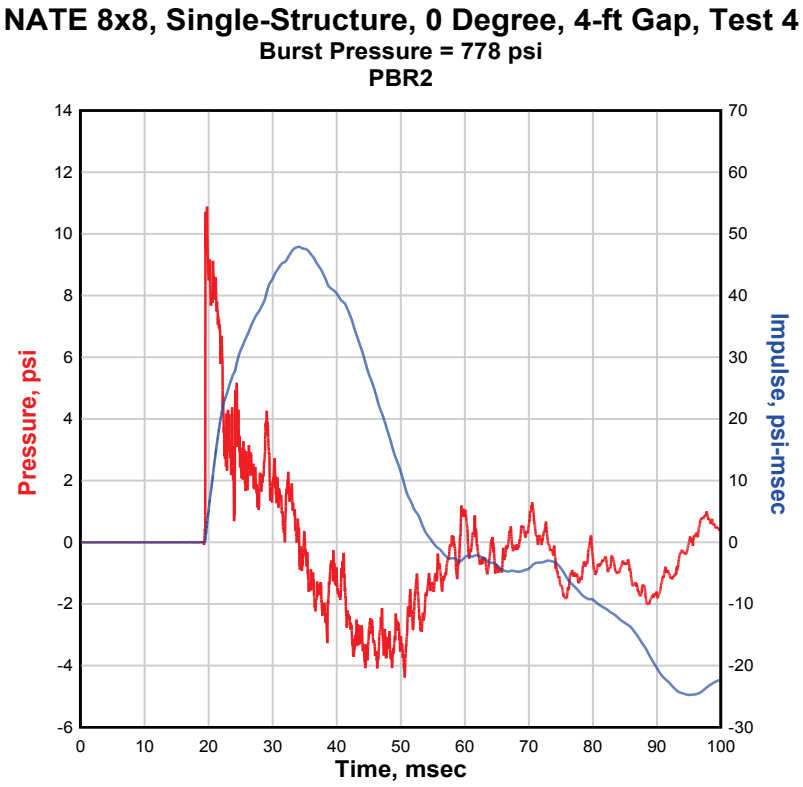

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

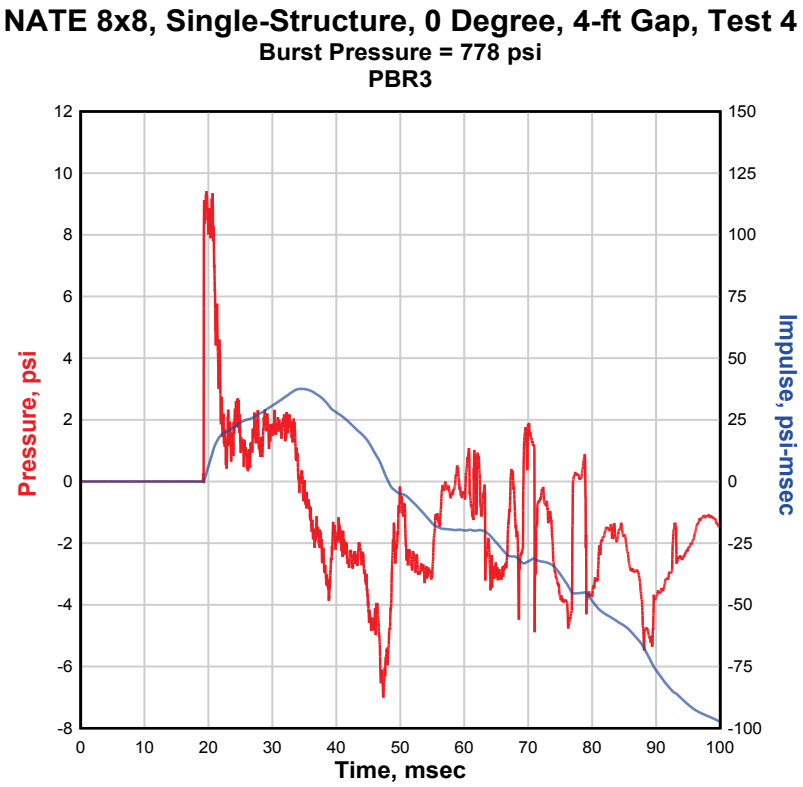

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

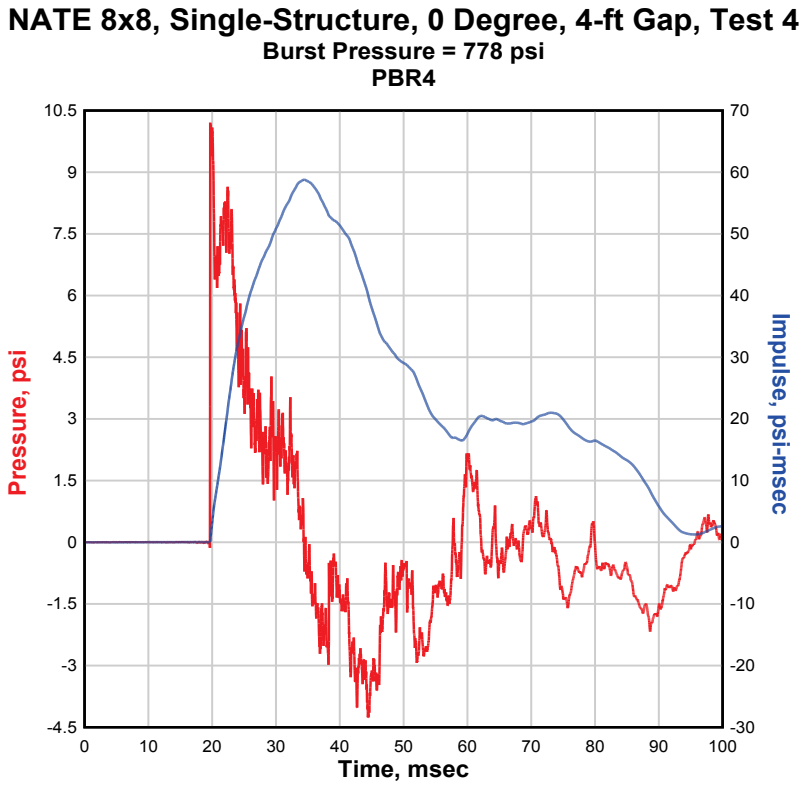

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

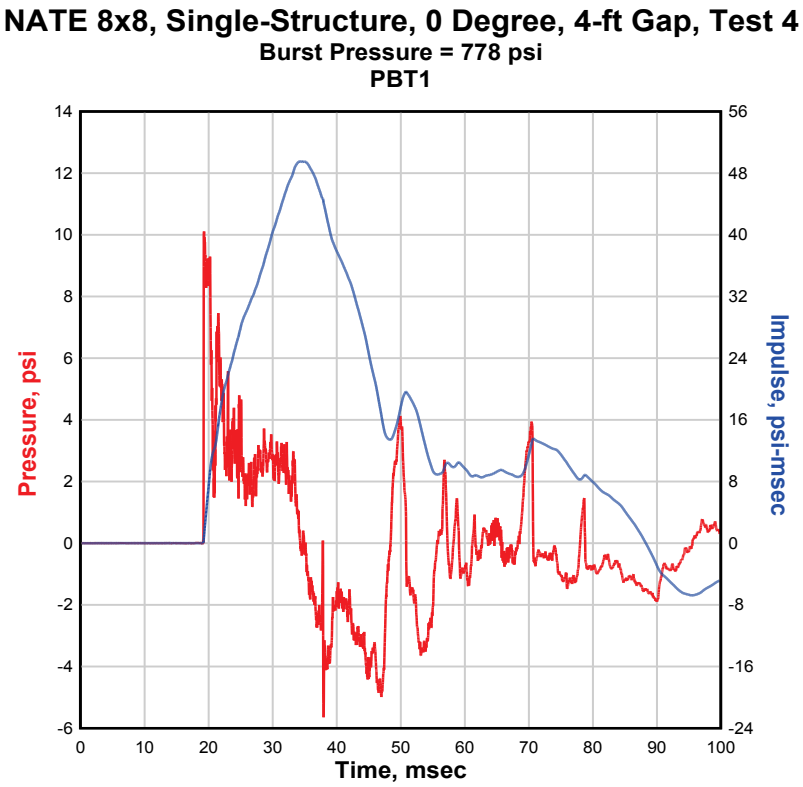

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
0
10
20
30
40
50
60
70
80
90
100

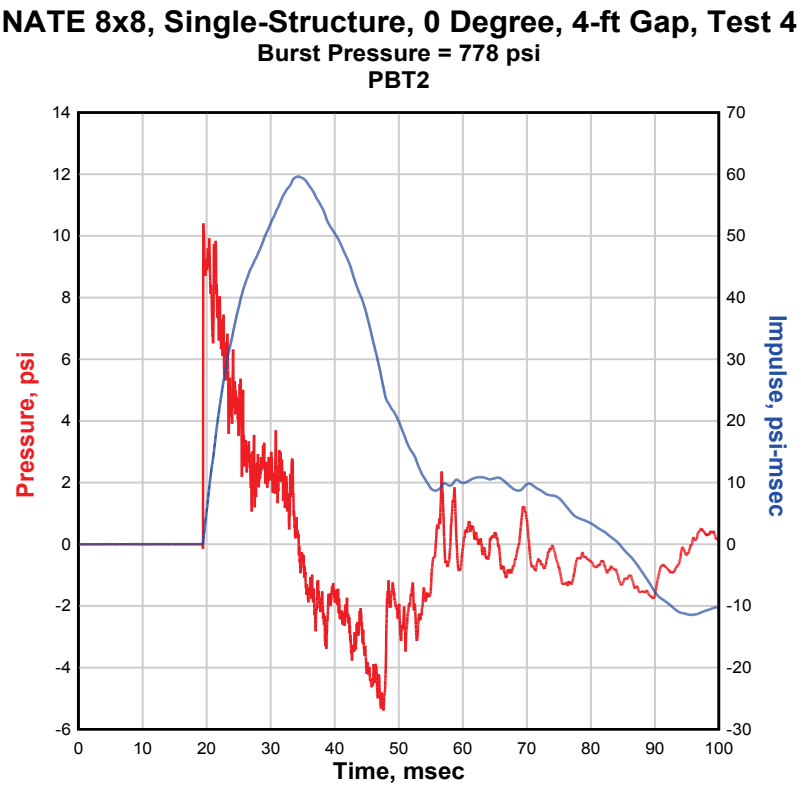

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

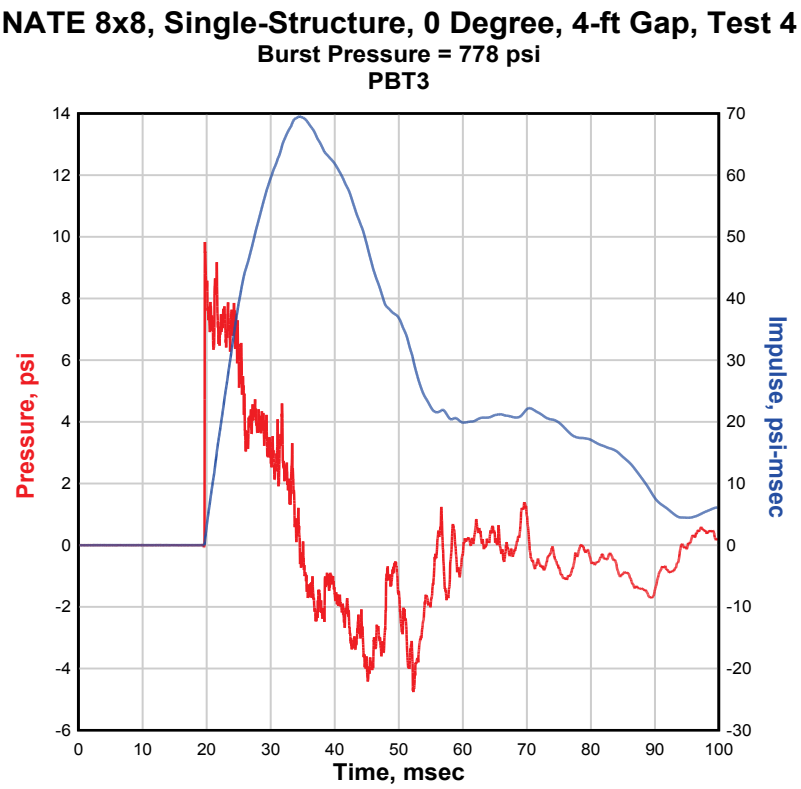

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
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-10
-20
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0
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30
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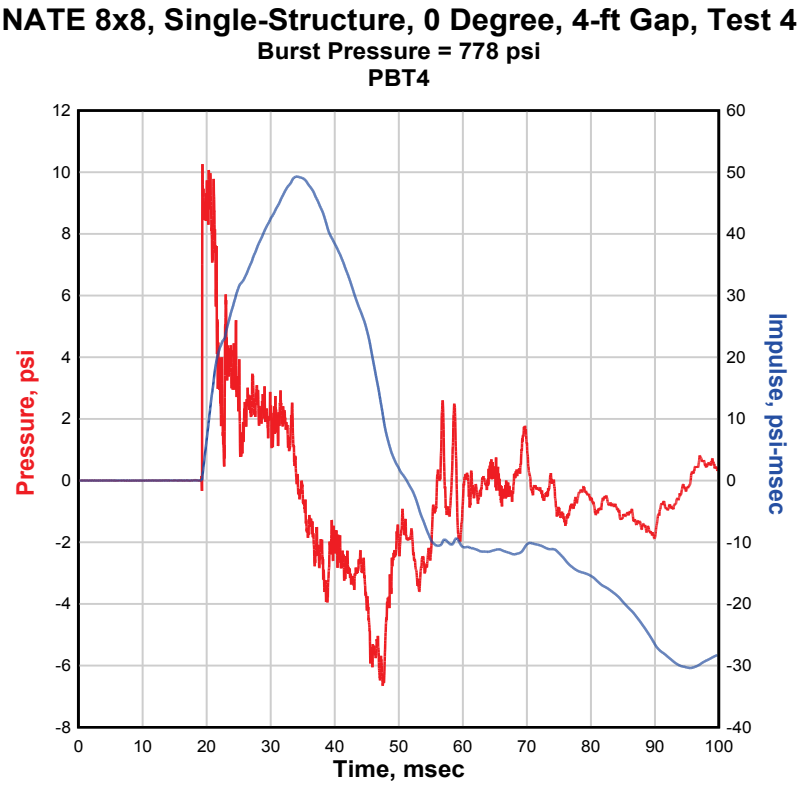
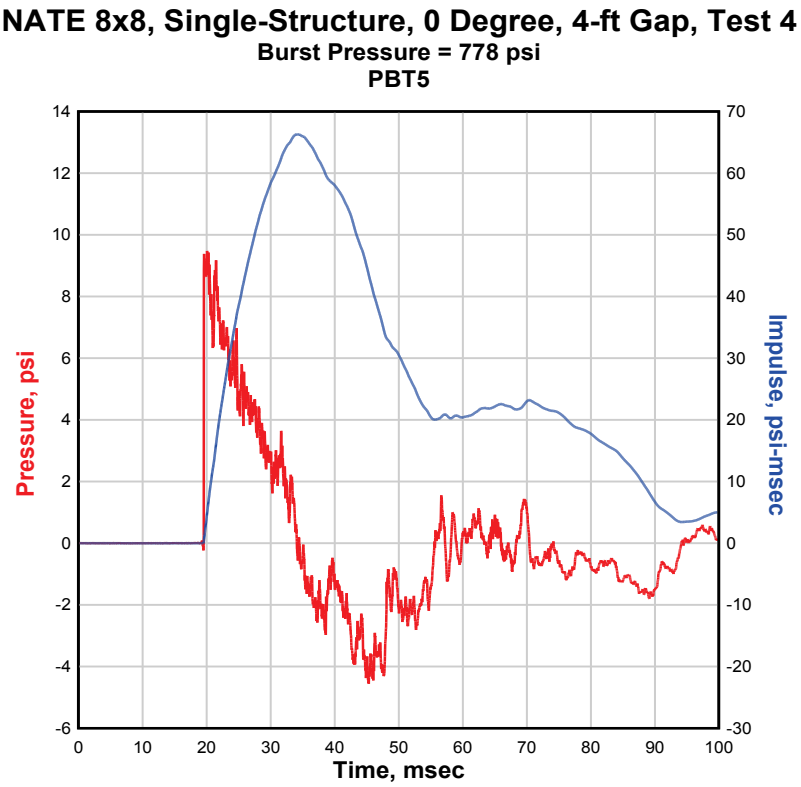
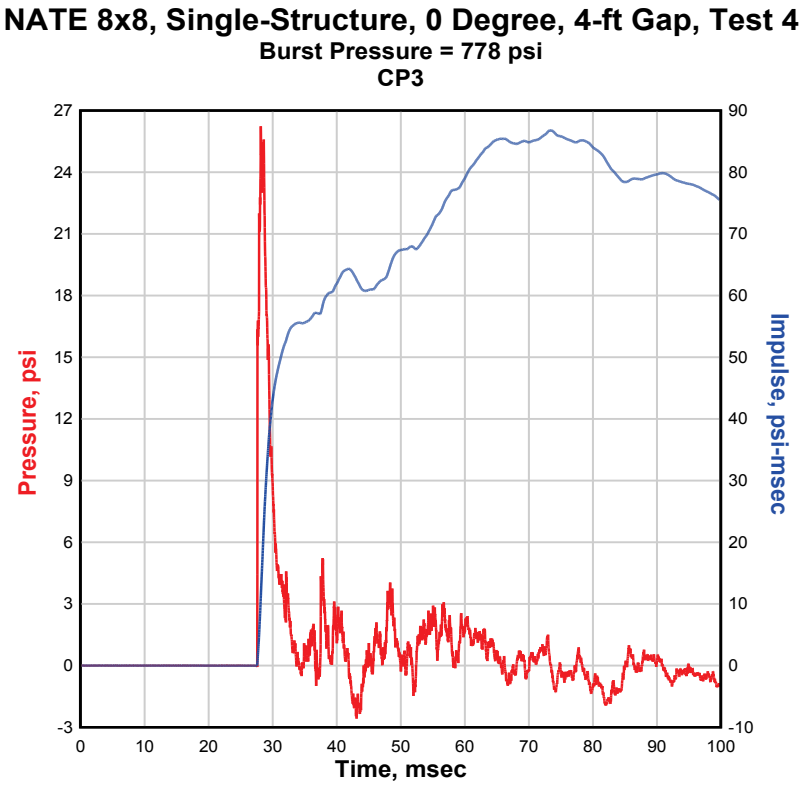
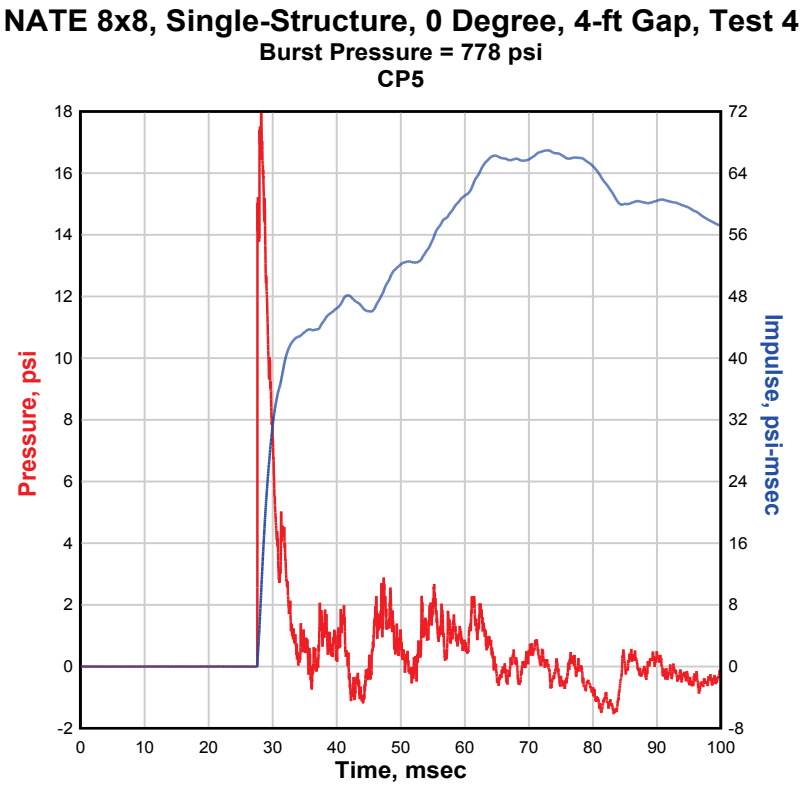
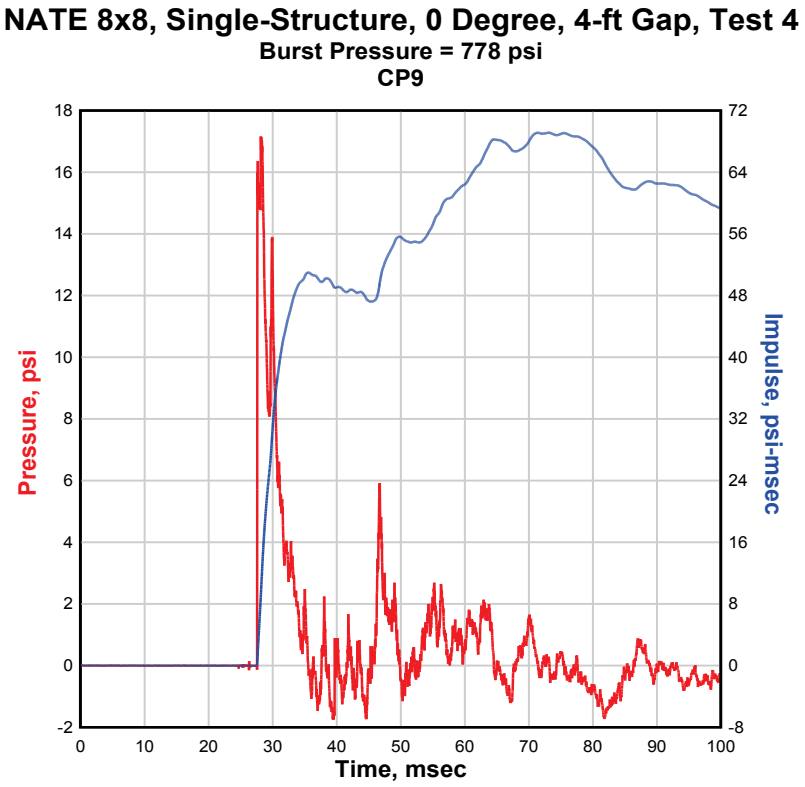
60
70
80
90
100

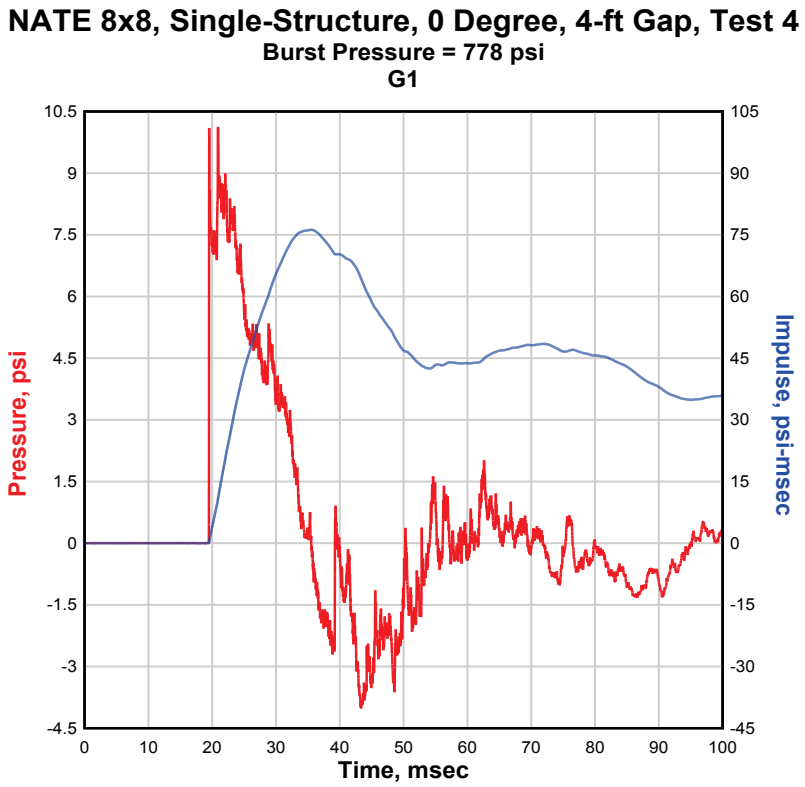

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec

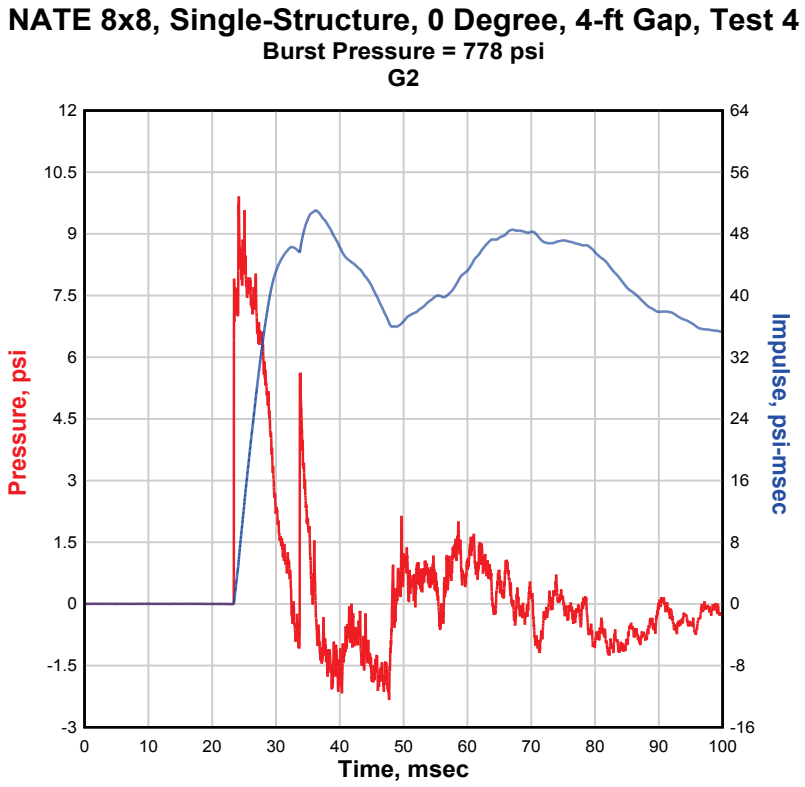

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec

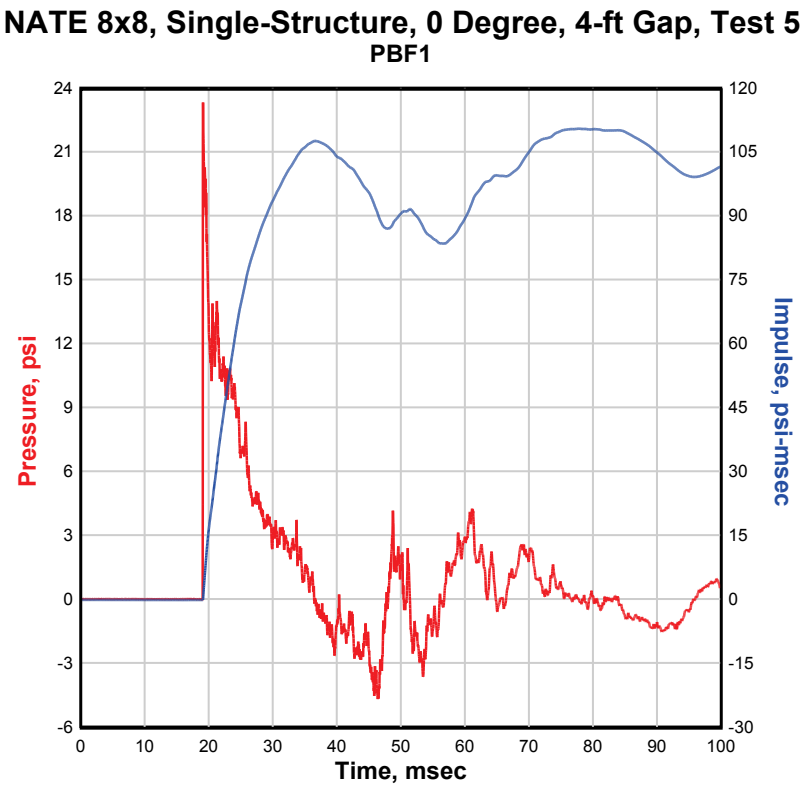

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

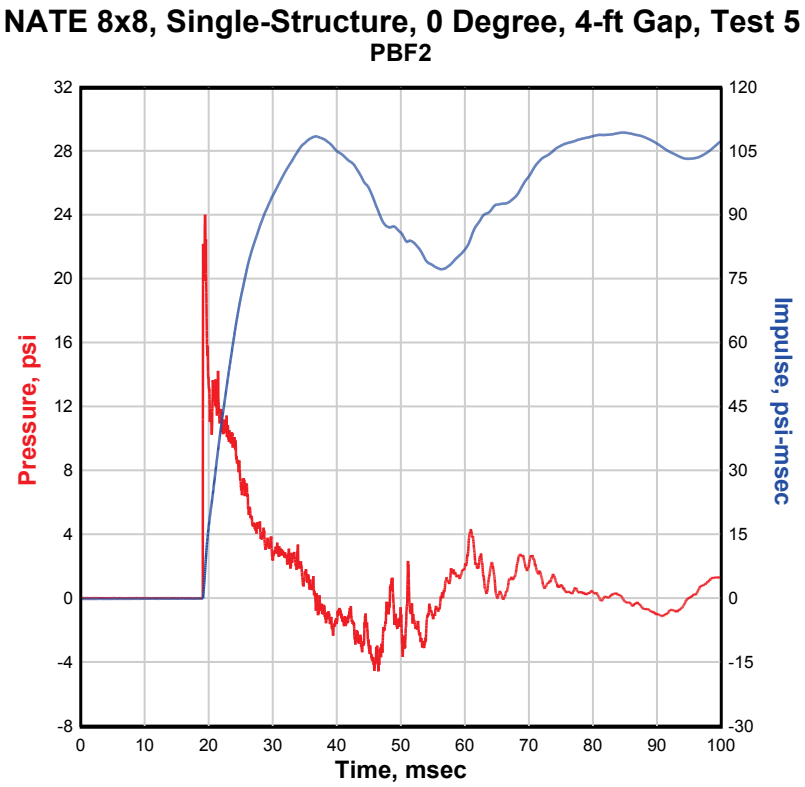

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
18
16
14
12
10
8
6
4
2
0
-2
72
64
56
48
40
32
24
16
8
0
-8
0
10
20
30
40
50
60
70
80
90
100

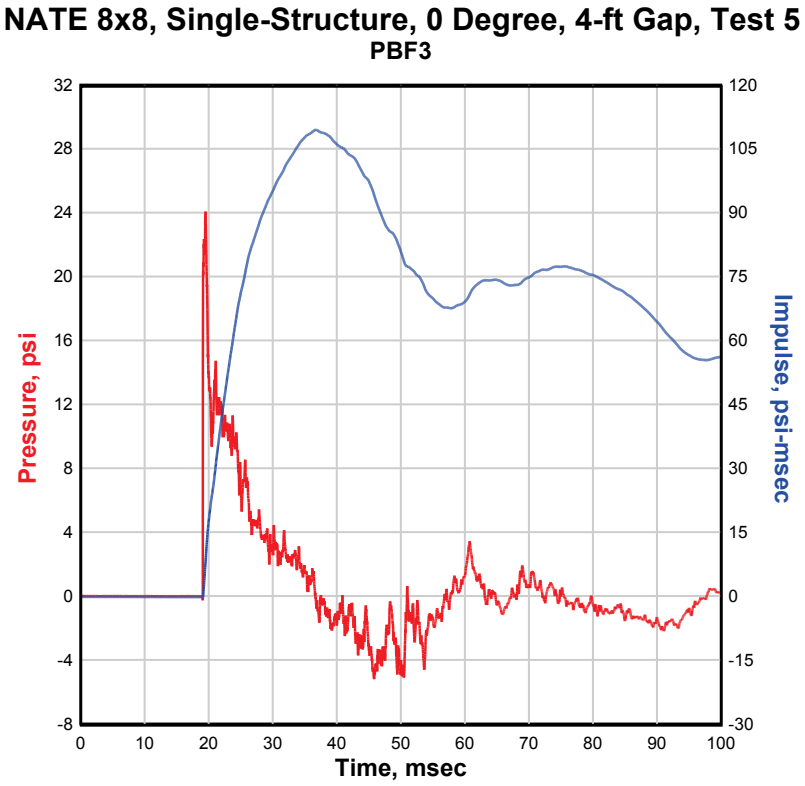

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
18
16
14
12
10
8
6
4
2
0
-2
72
64
56
48
40
32
24
16
8
0
-8
0
10
20
30
40
50
60
70
80
90
100

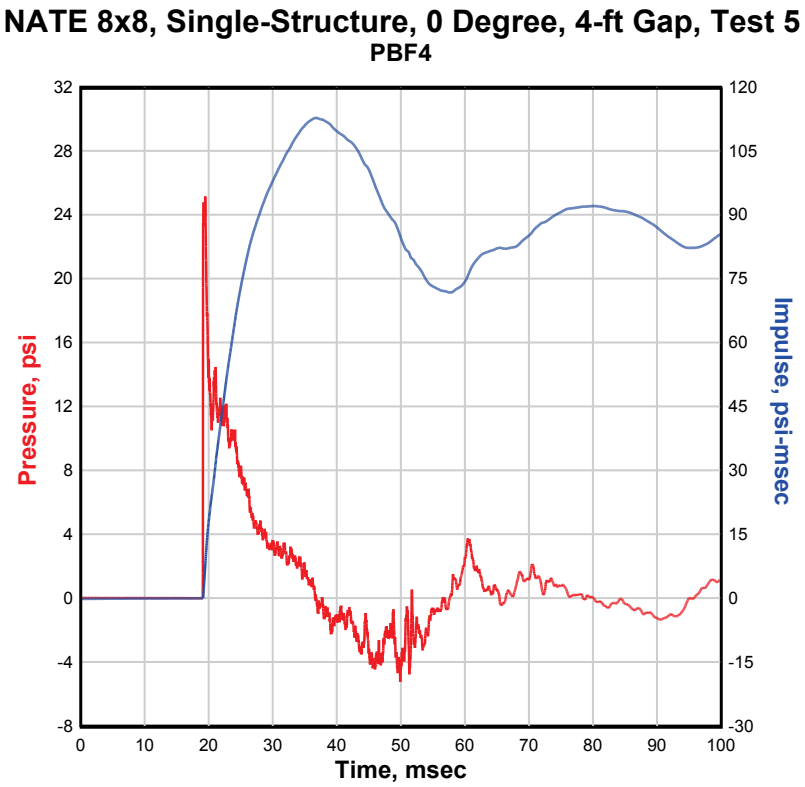

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
G1
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

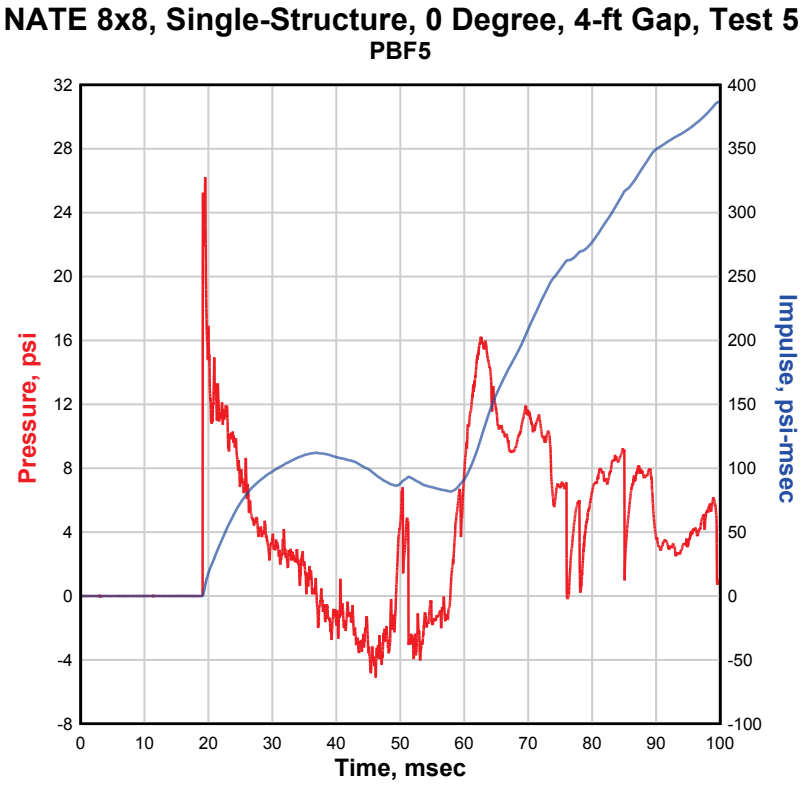

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 4
Burst Pressure = 778 psi
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

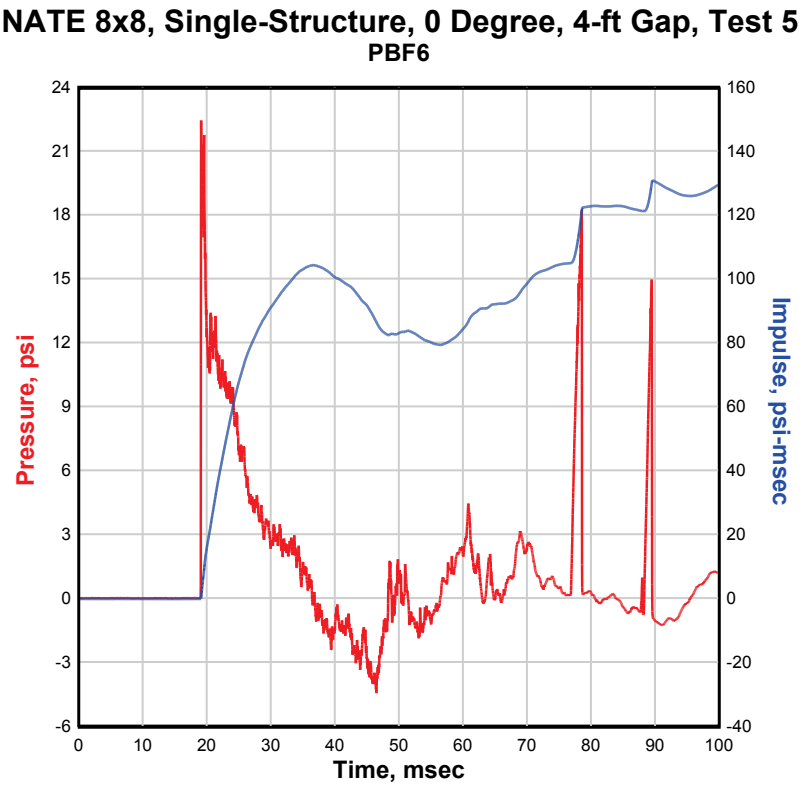

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

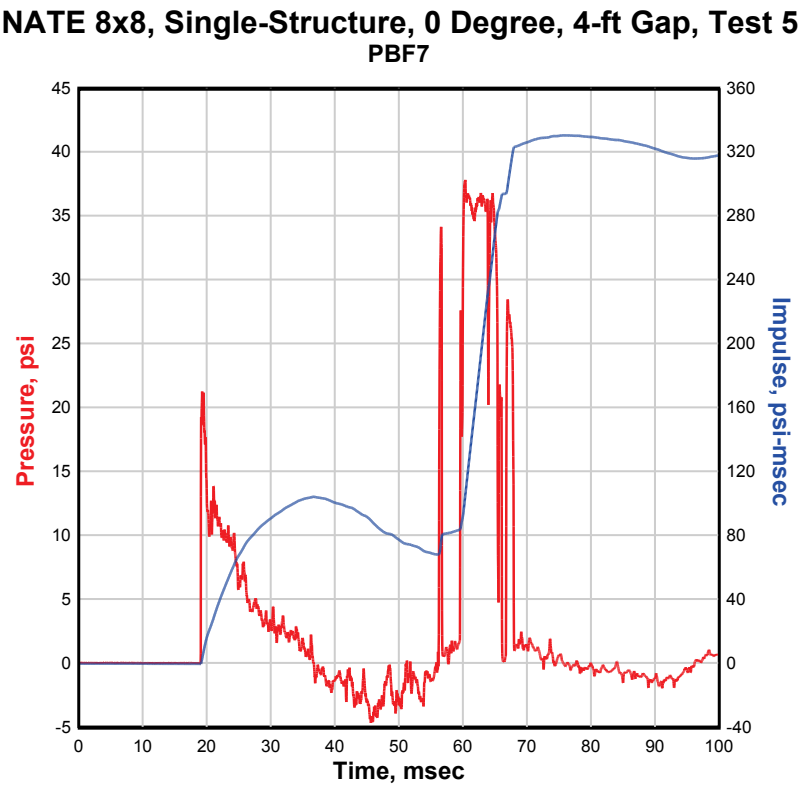

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

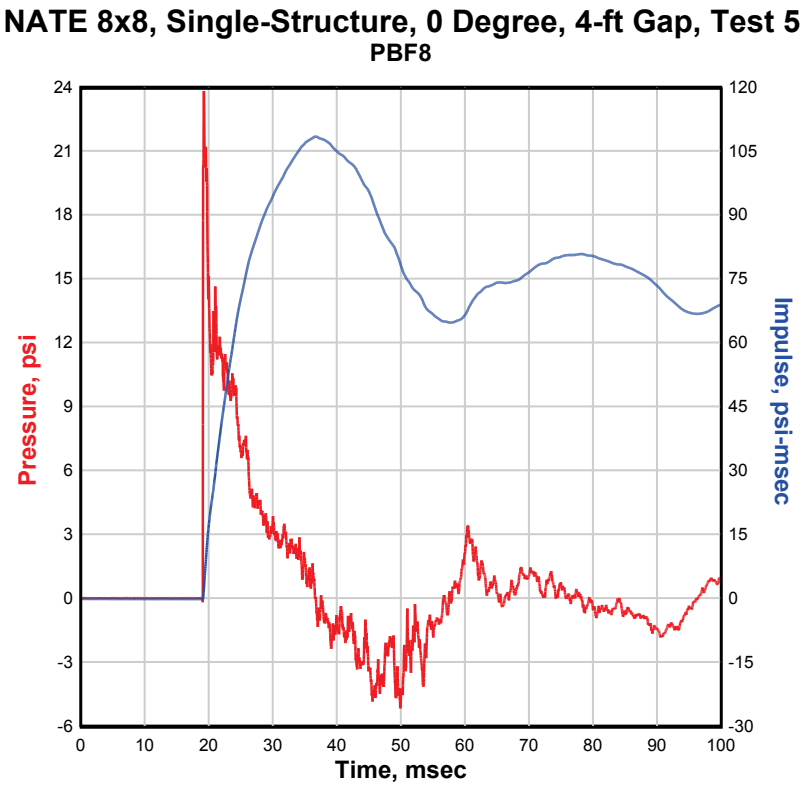

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

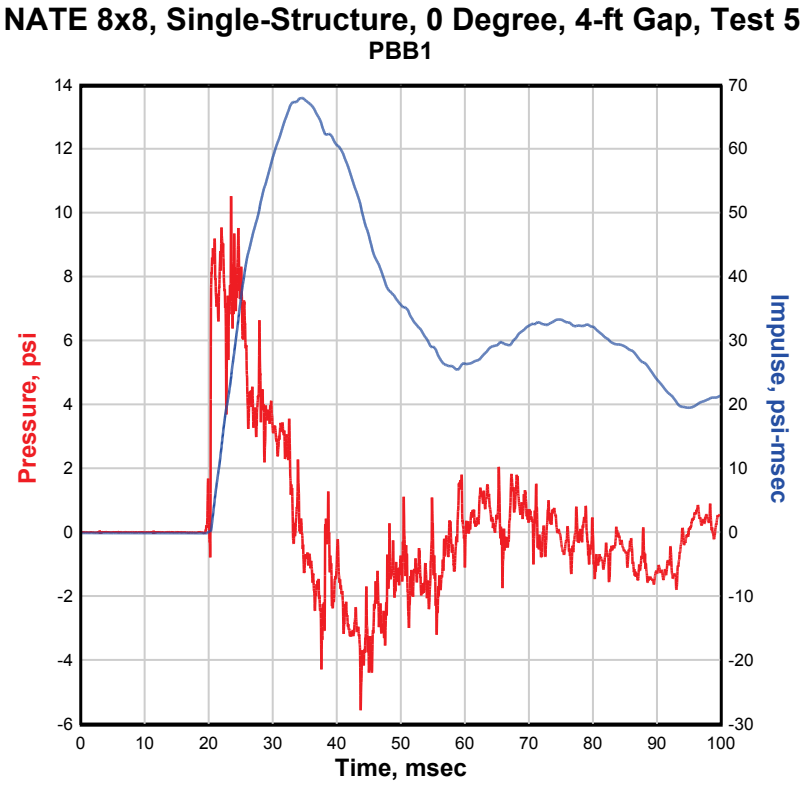

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

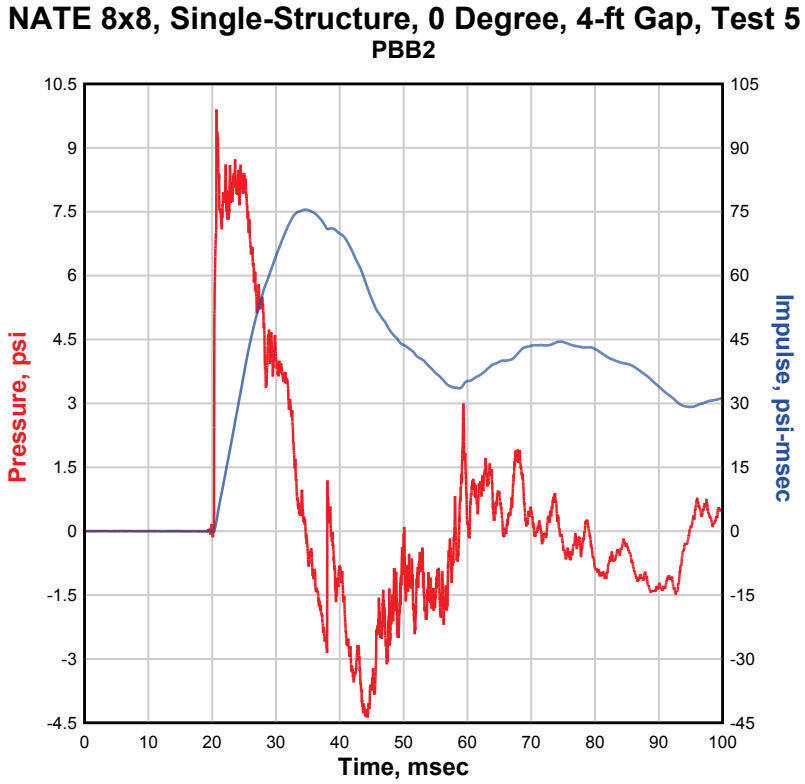

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
400
350
300
250
200
150
100
50
0
-50
-100
0
10
20
30
40
50
60
70
80
90
100

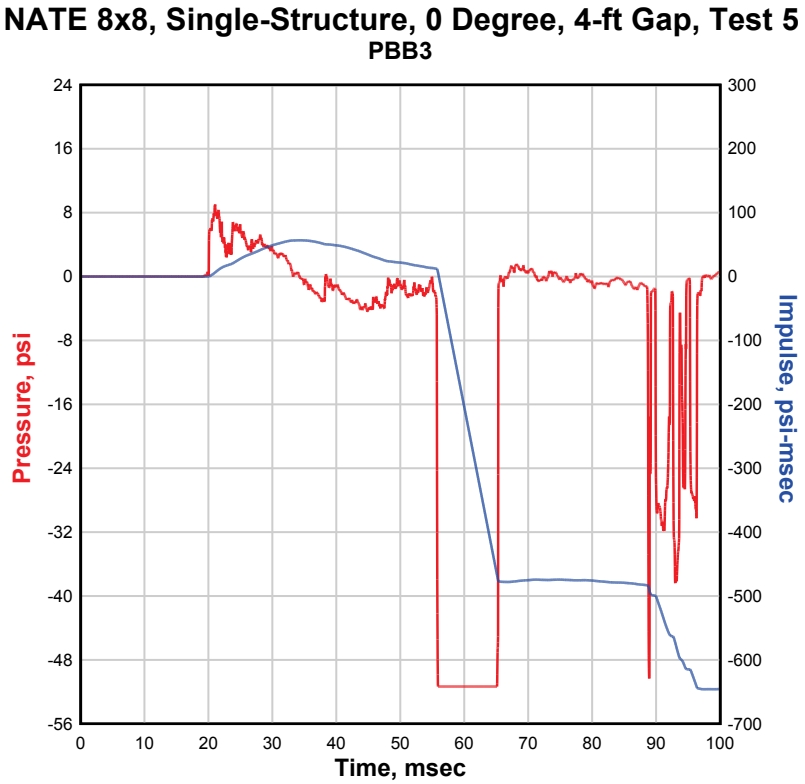

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
160
140
120
100
80
60
40
20
0
-20
-40
0
10
20
30
40
50
60
70
80
90
100

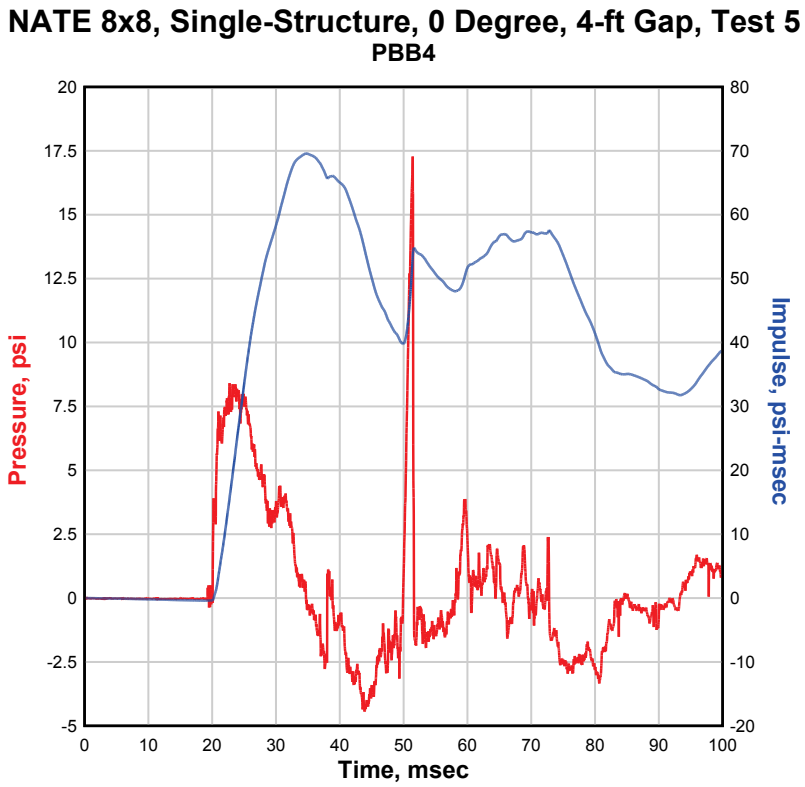

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
45
40
35
30
25
20
15
10
5
0
-5
360
320
280
240
200
160
120
80
40
0
-40
0
10
20
30
40
50
60
70
80
90
100

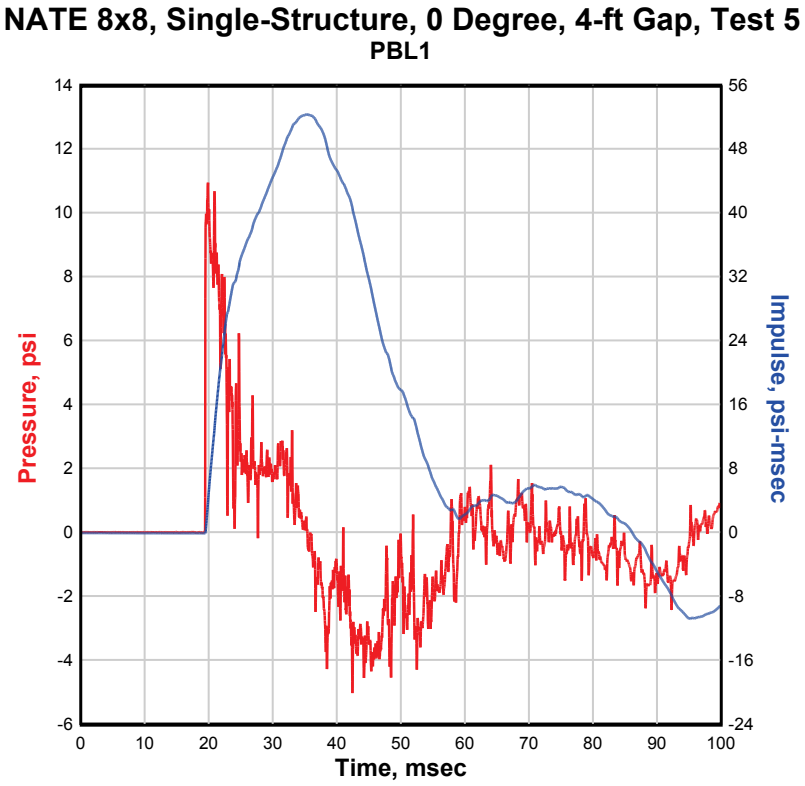

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

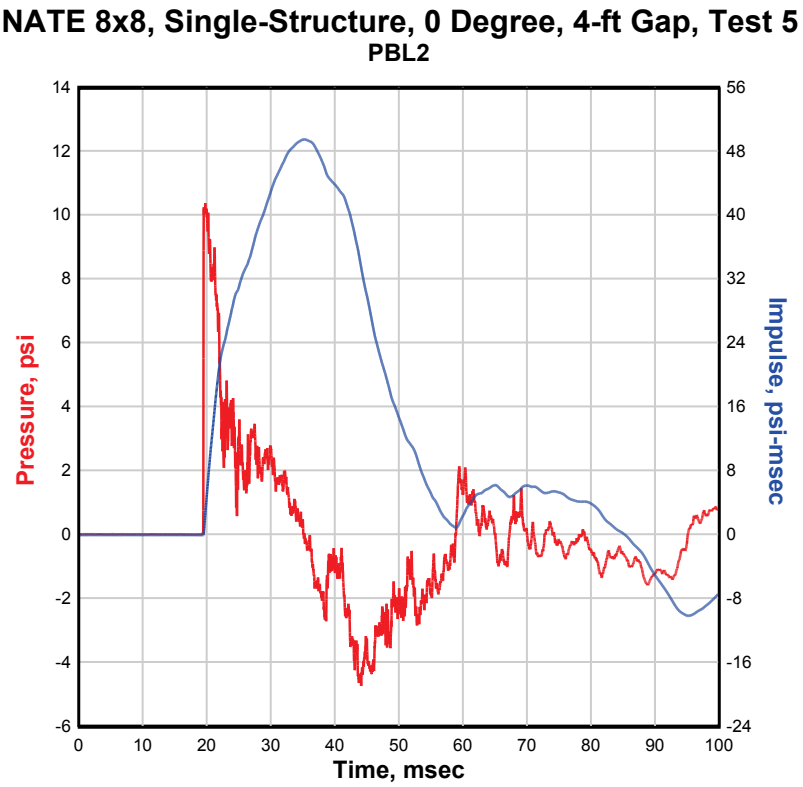

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

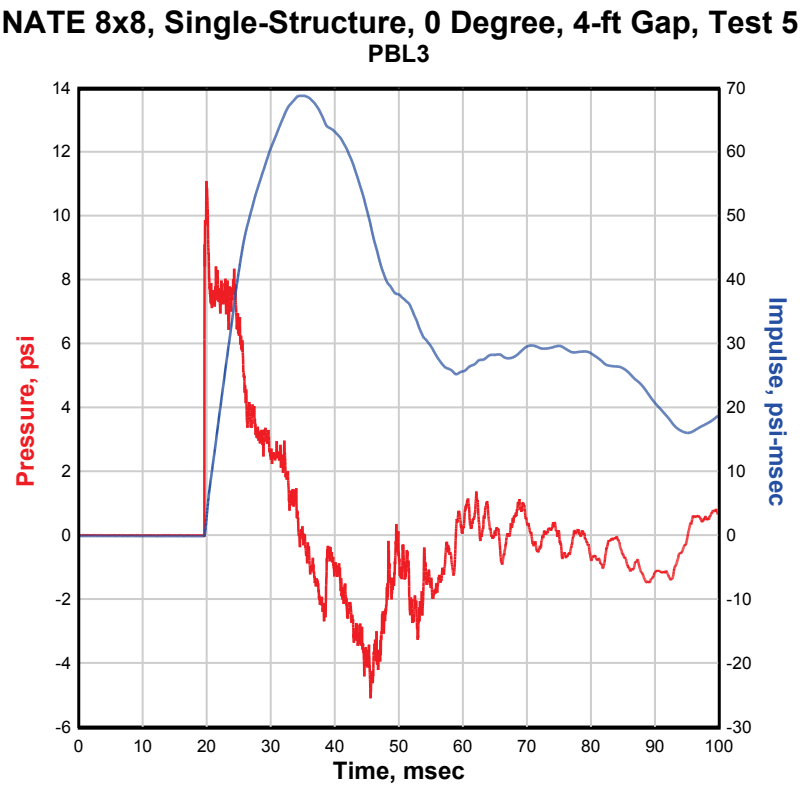

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

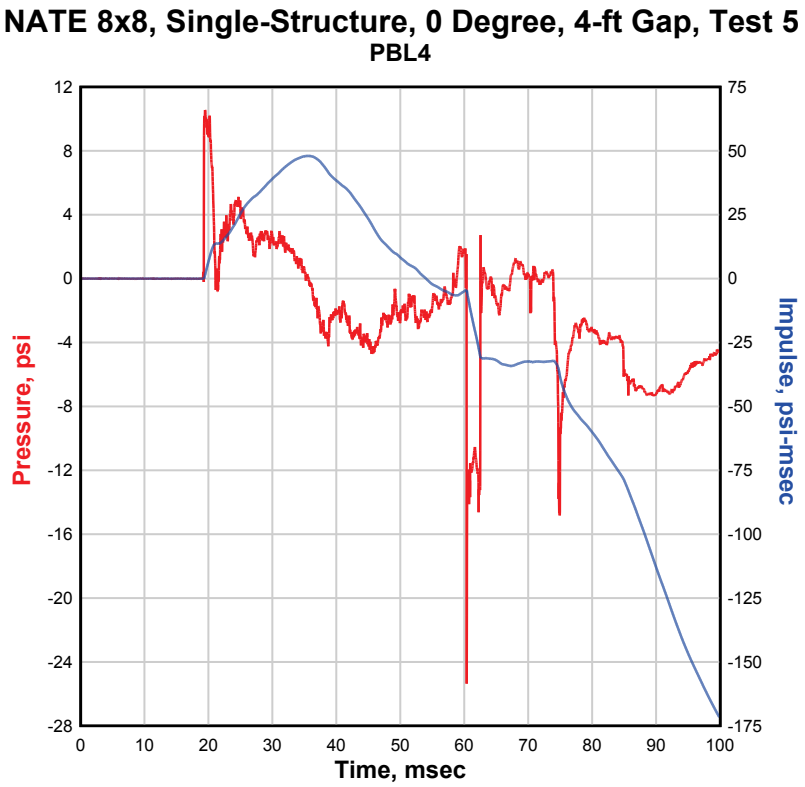

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
0
10
20
30
40
50
60
70
80
90
100

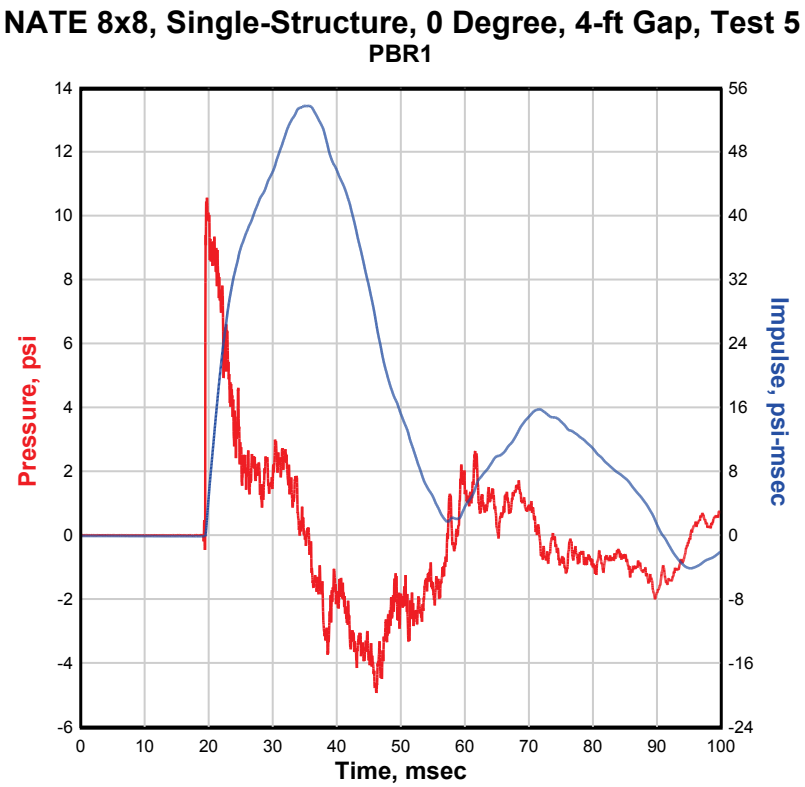

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
80
70
60
50
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100

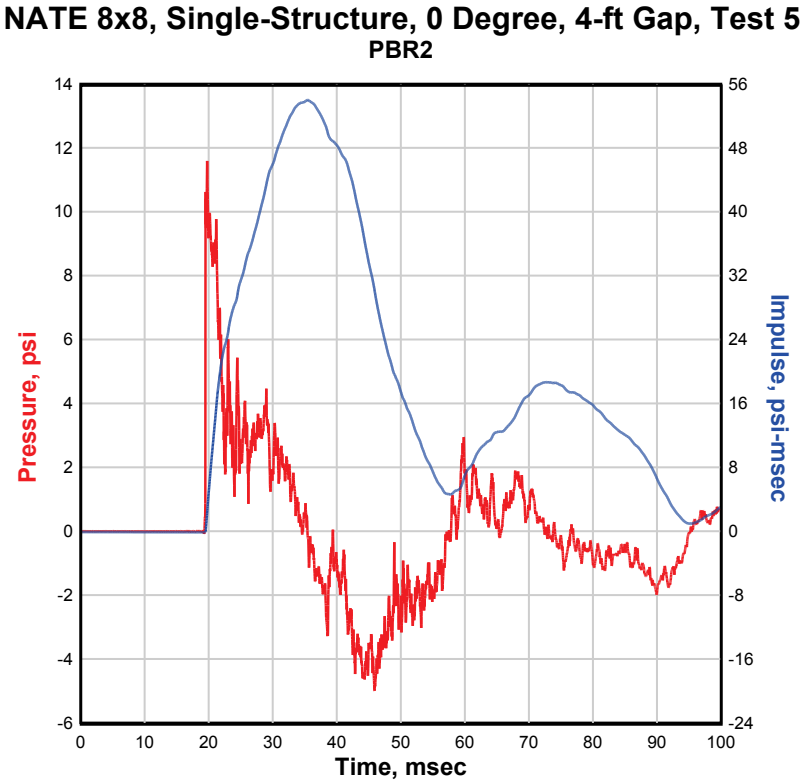

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

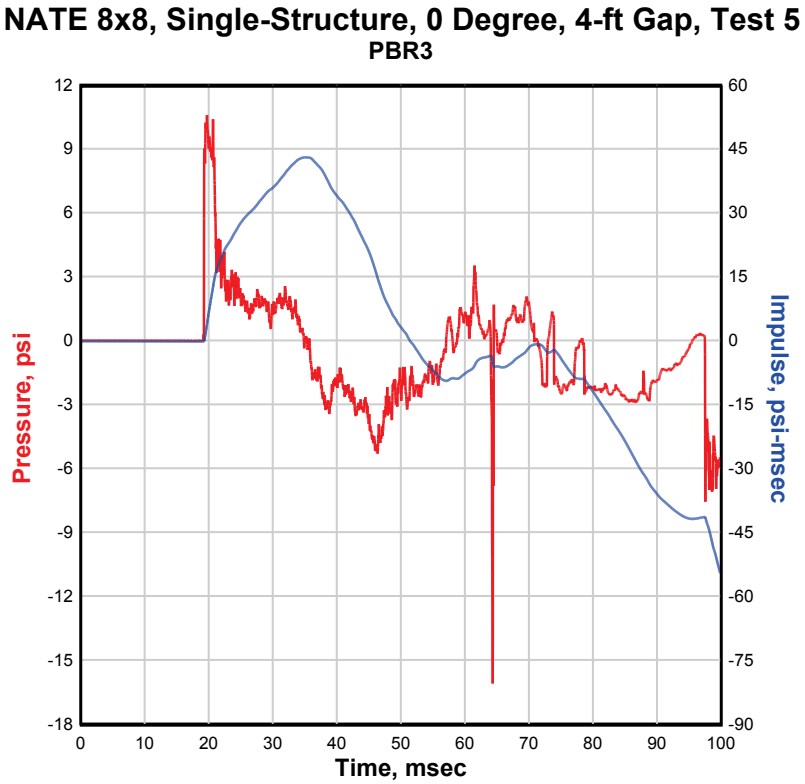

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

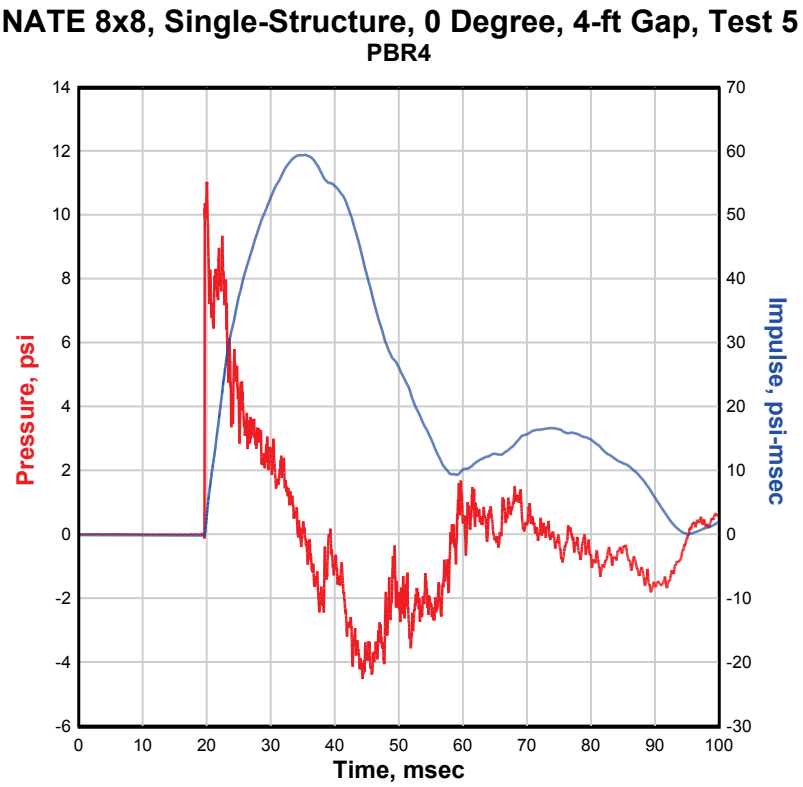

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

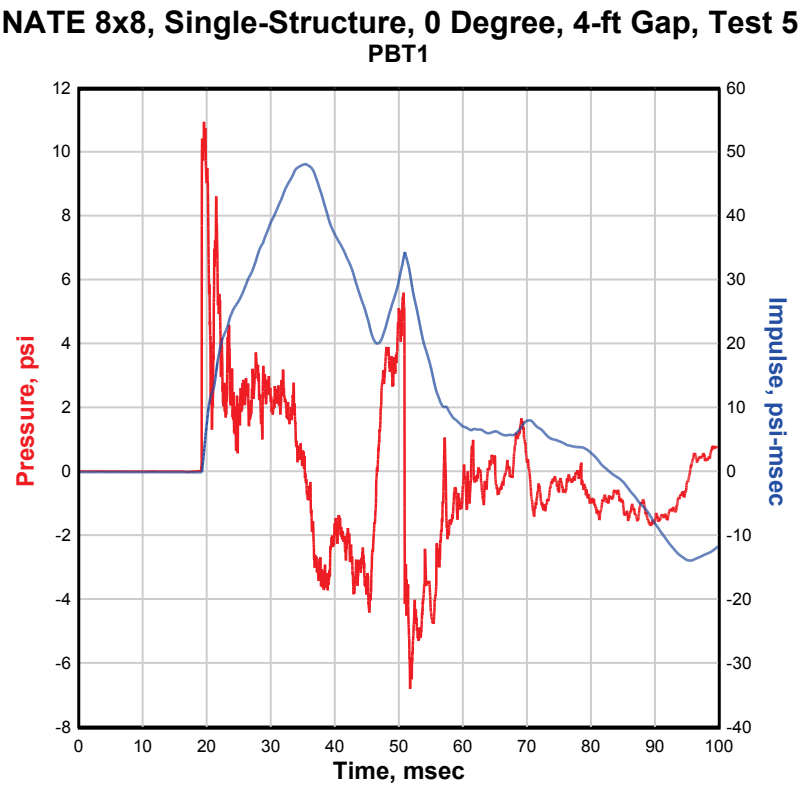

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
12
8
4
0
-4
-8
-12
-16
-20
-24
-28
75
50
25
0
-25
-50
-75
-100
-125
-150
-175
0
10
20
30
40
50
60
70
80
90
100

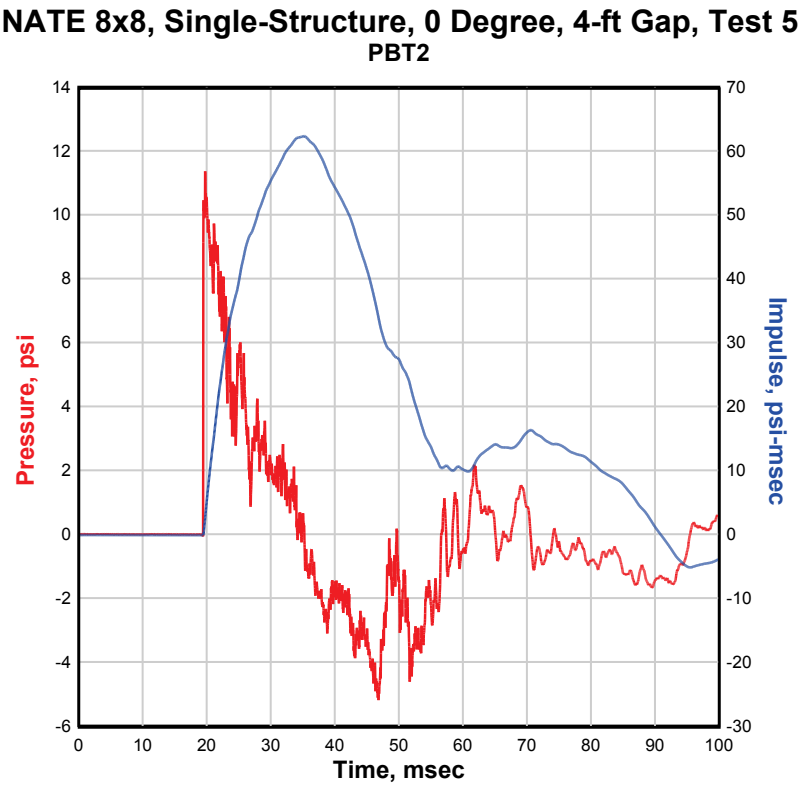

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

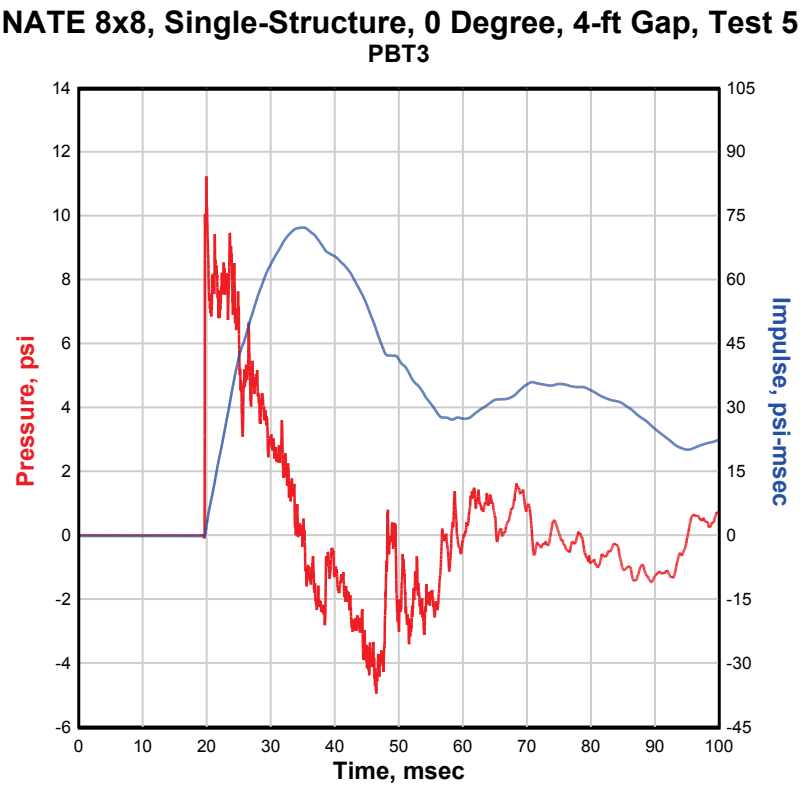

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

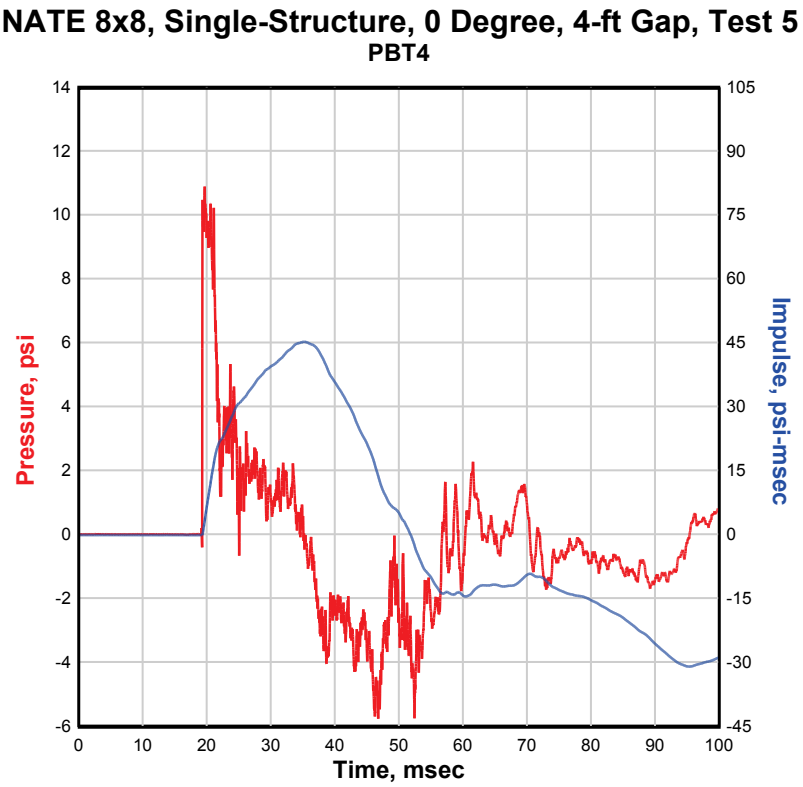

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
12
9
6
3
0
-3
-6
-9
-12
-15
-18
60
45
30
15
0
-15
-30
-45
-60
-75
-90
0
10
20
30
40
50
60
70
80
90
100

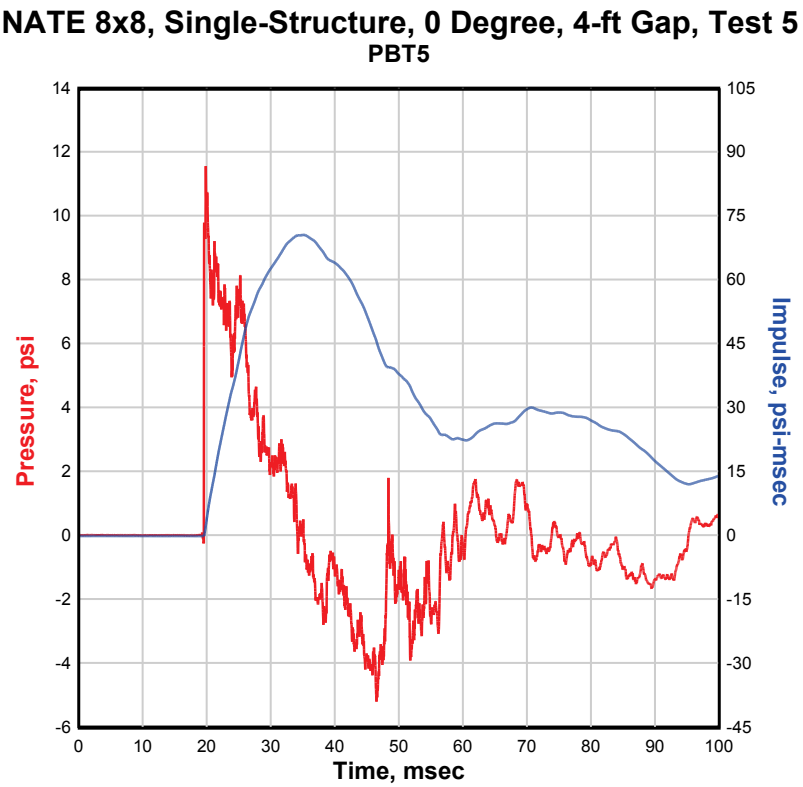

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

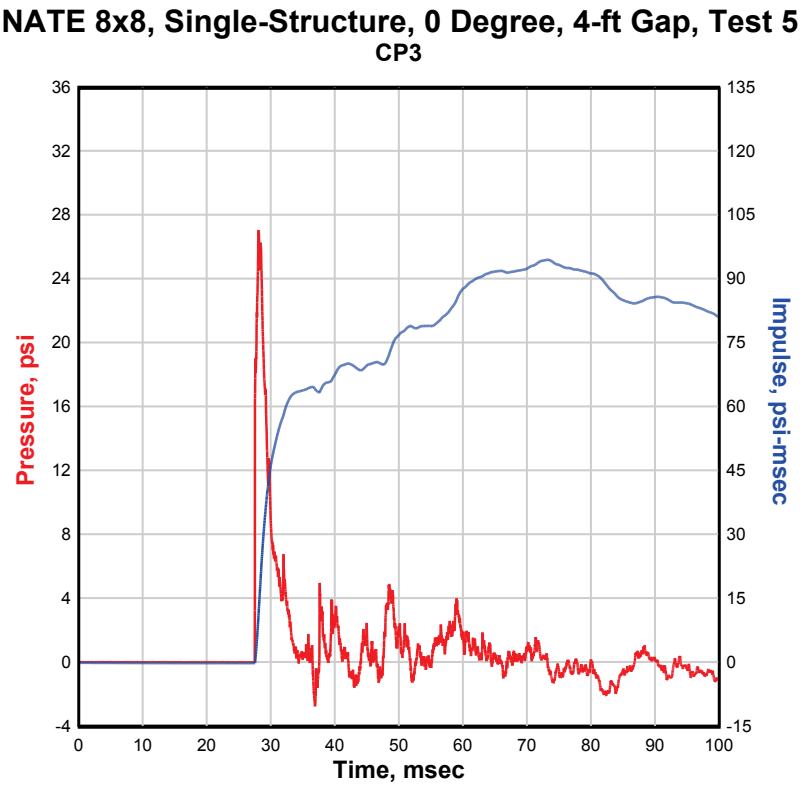

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100

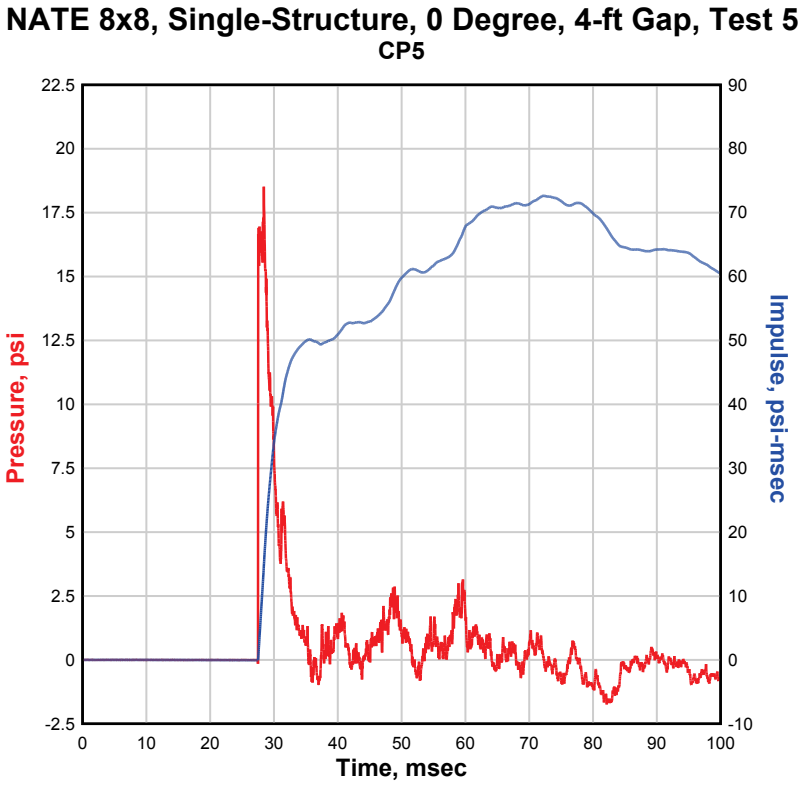

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

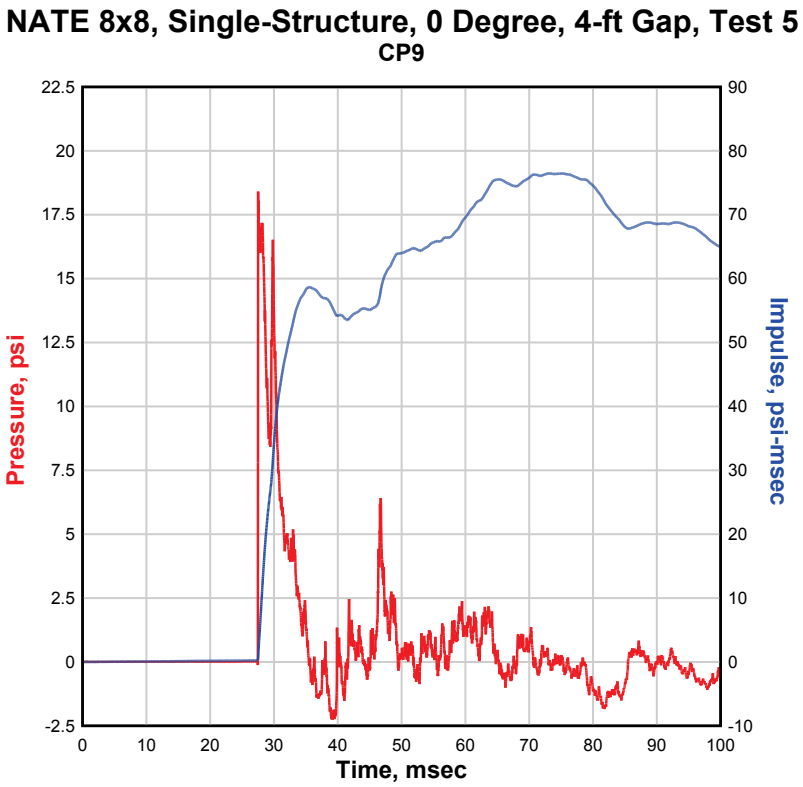

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

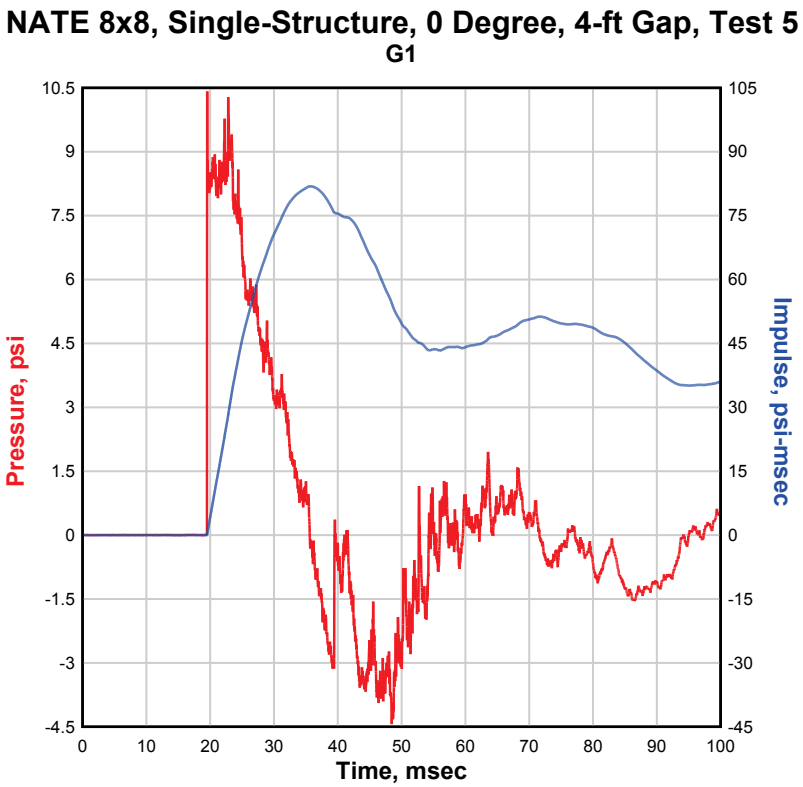

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

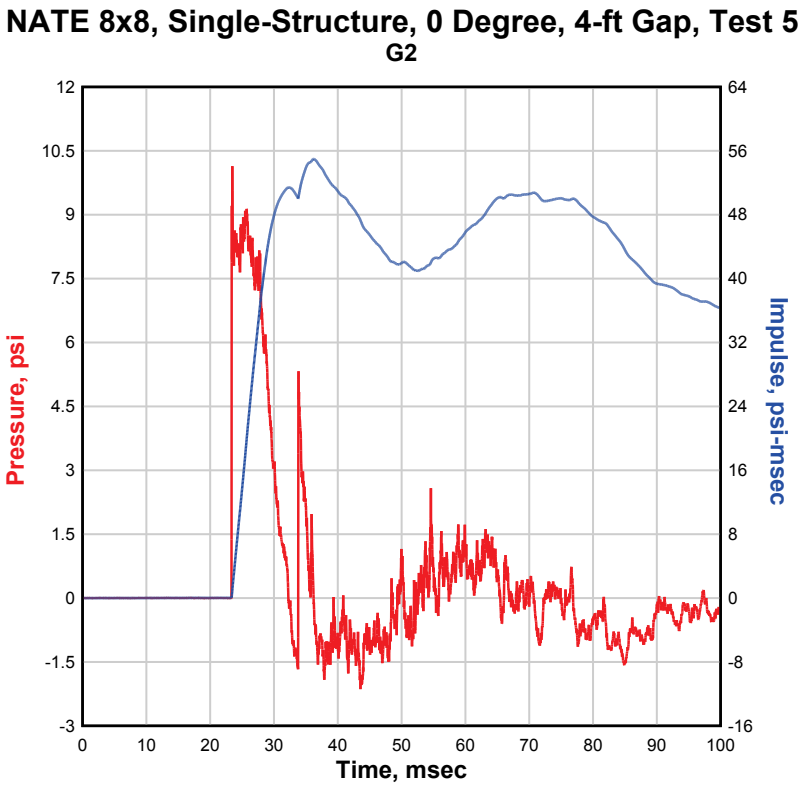

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

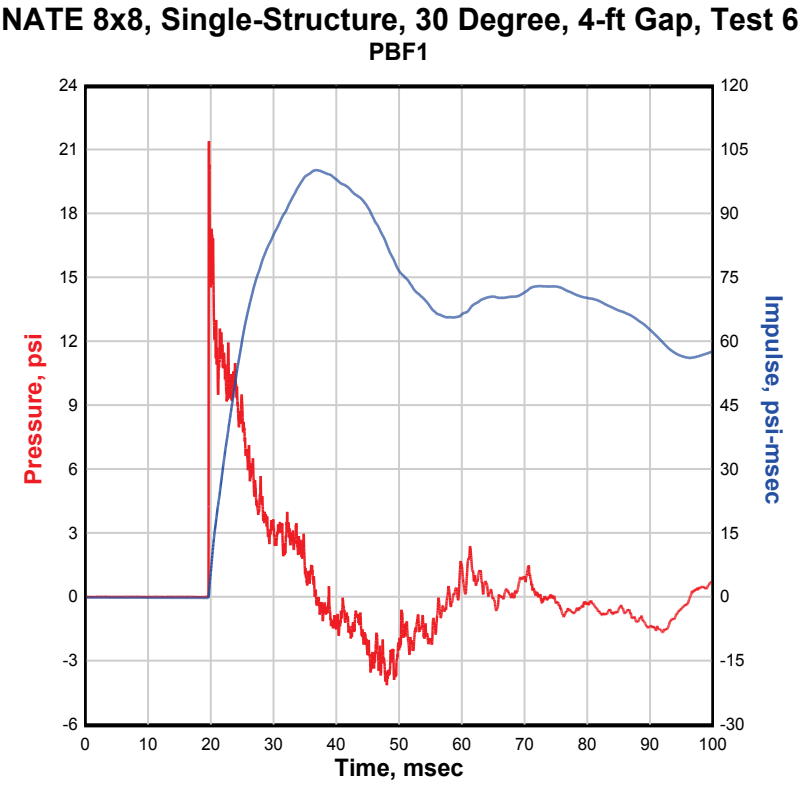

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

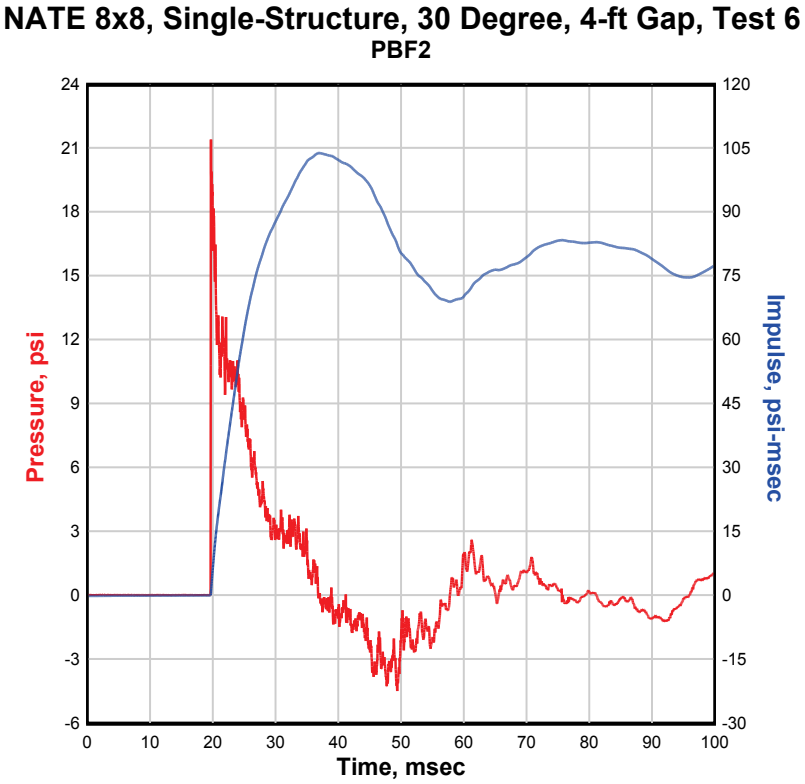

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

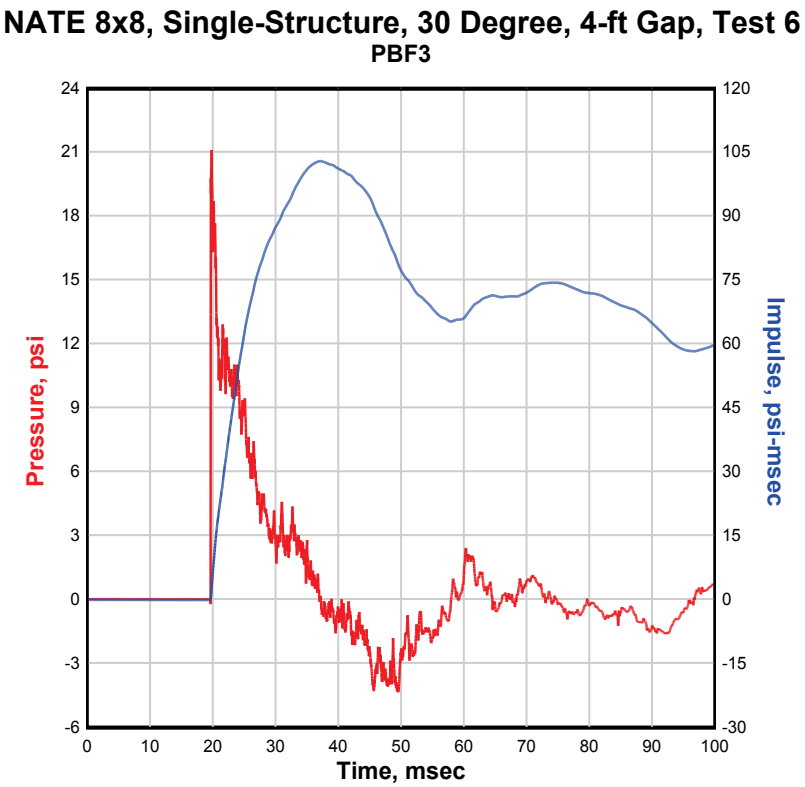

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
G1
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

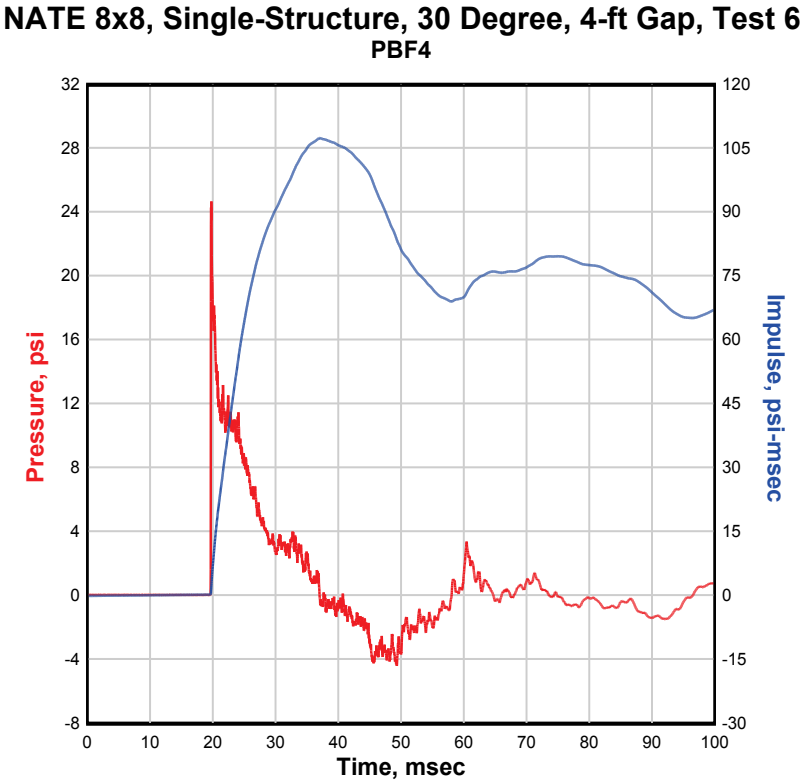

NATE 8x8, Single-Structure, 0 Degree, 4-ft Gap, Test 5
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

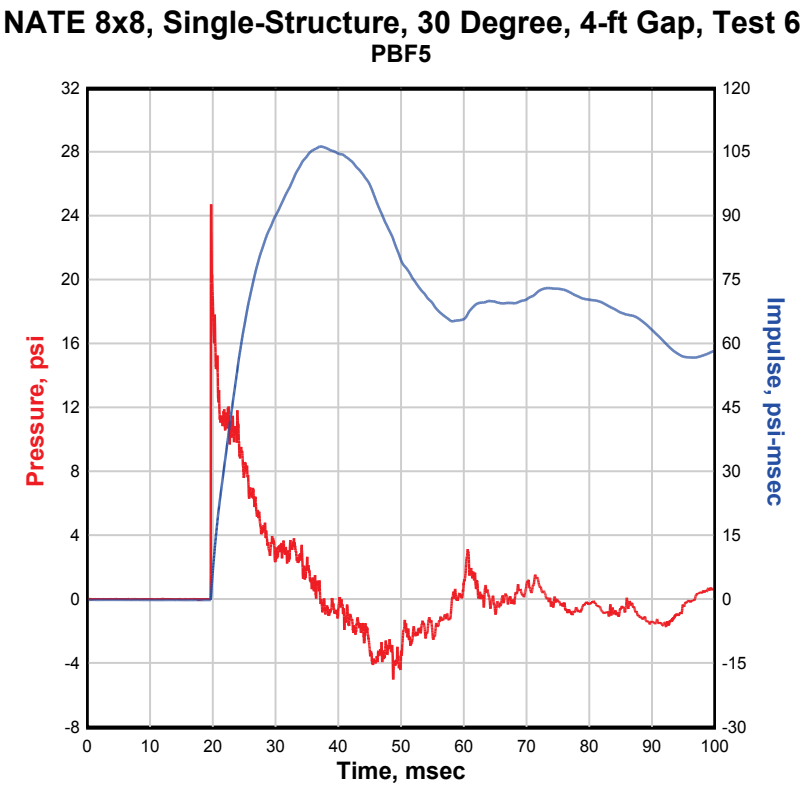
Appendix B: Pressure and Impulse Data from Tests with 30-Degree Obliquity, 4-ft Gap

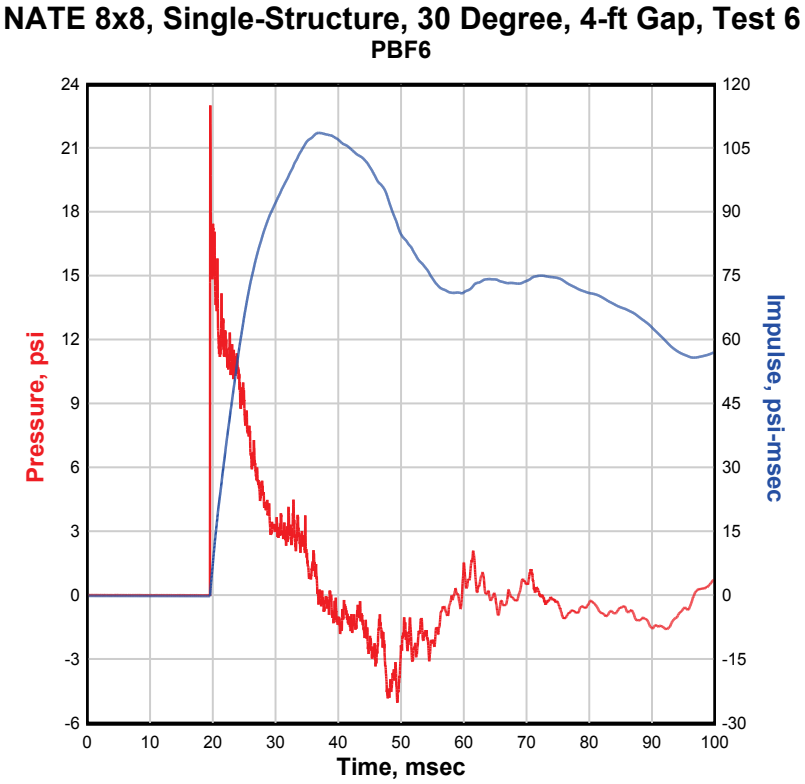


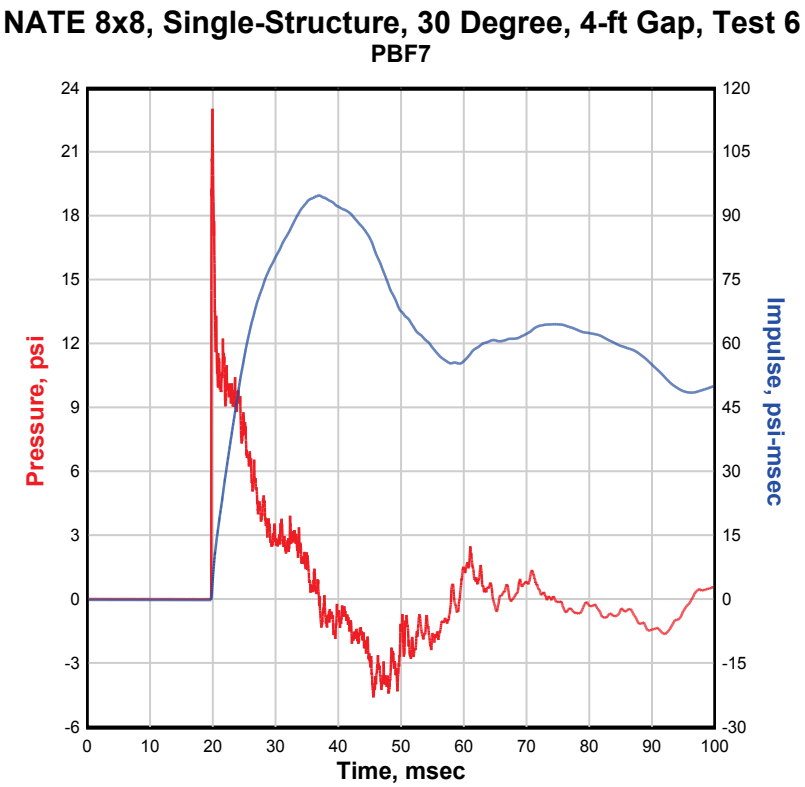

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

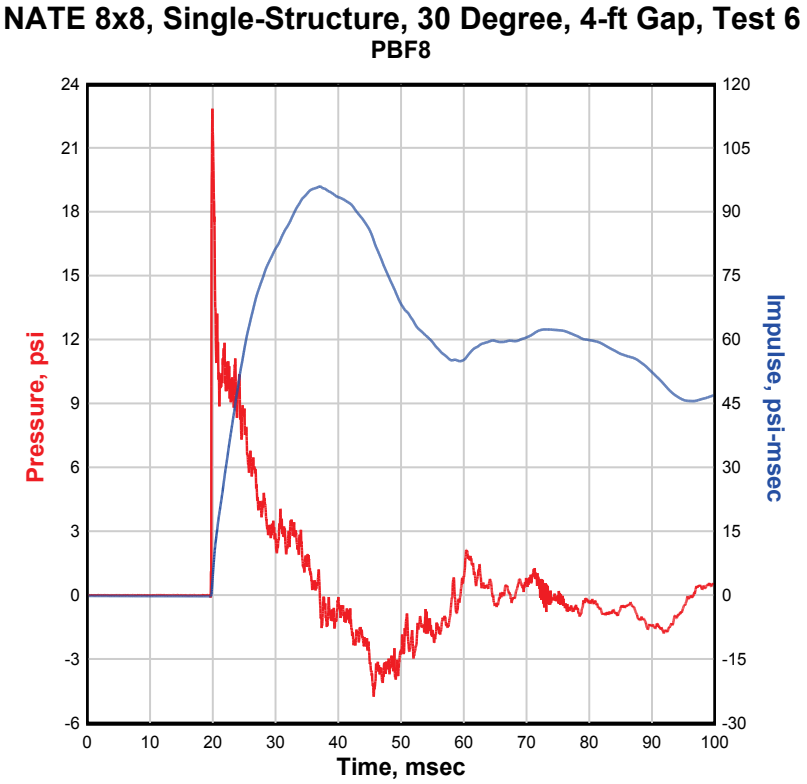

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

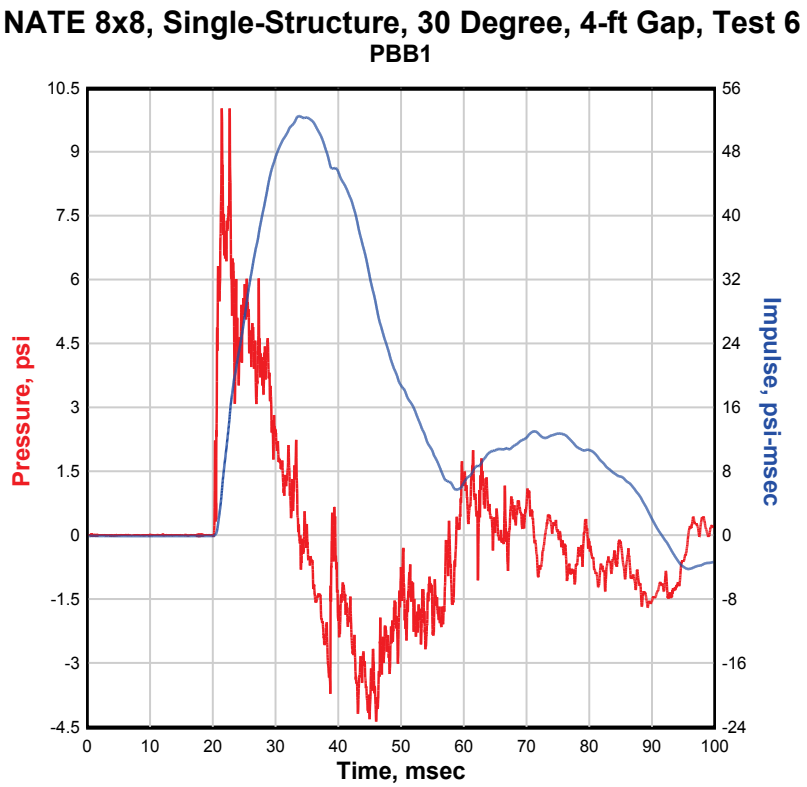

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
56
48
40
32
24
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-8
-16
-24
0
10
20
30
40
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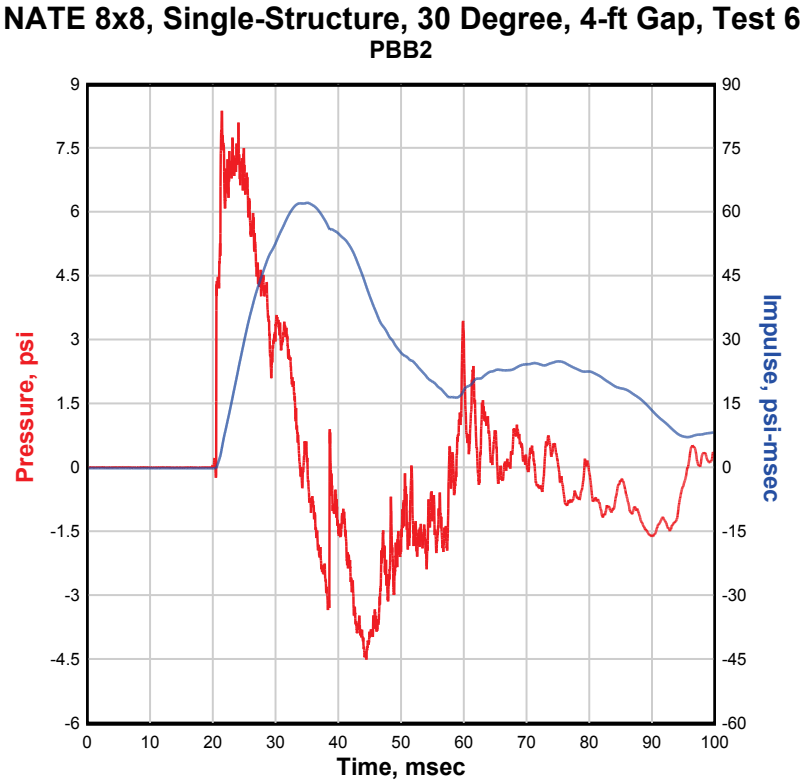
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
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60
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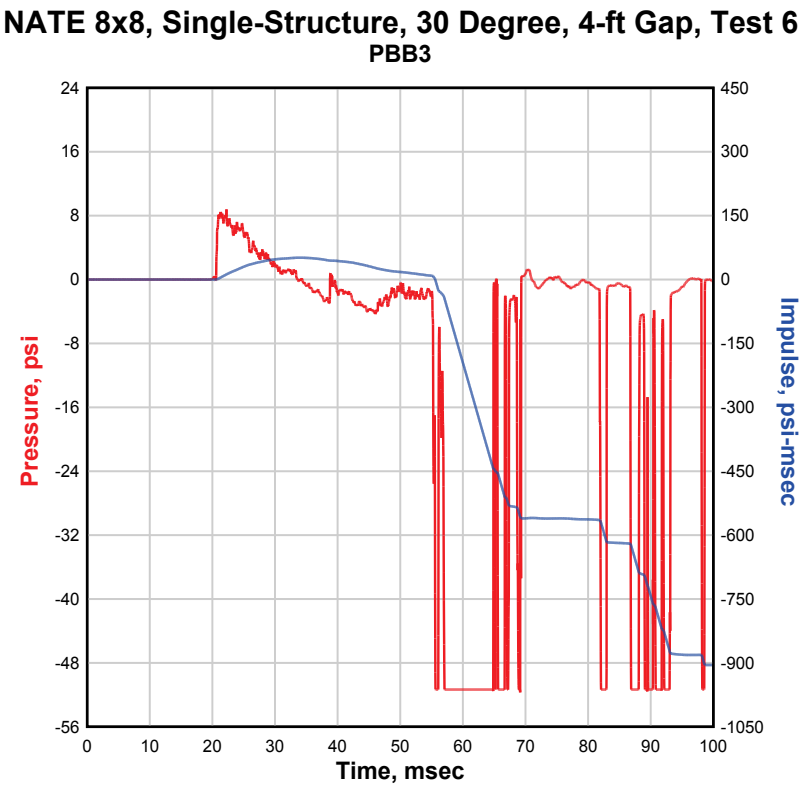
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
450
300
150
0
-150
-300
-450
-600
-750
-900
-1050
0
10
20
30
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60
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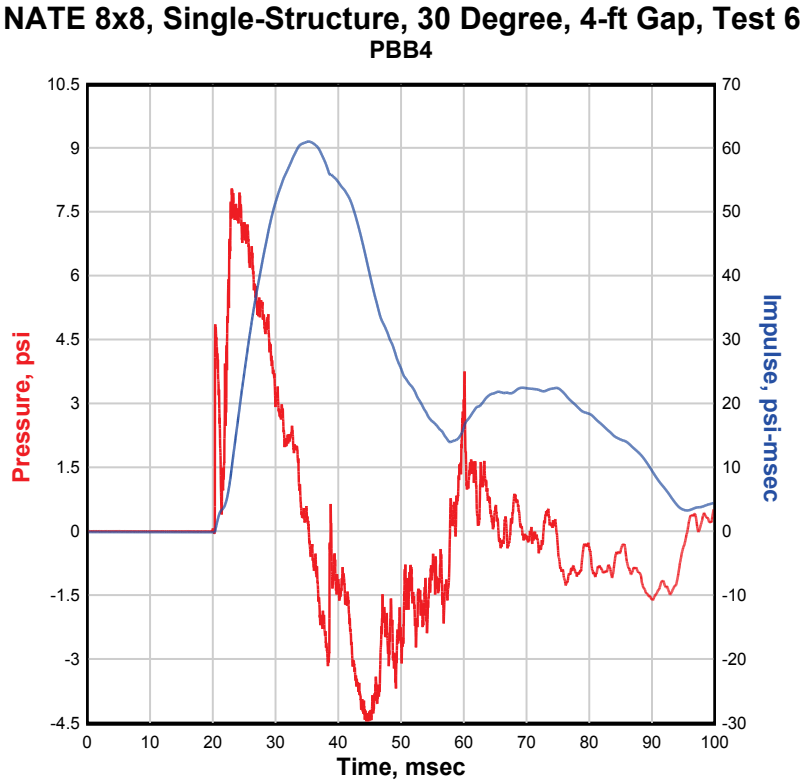
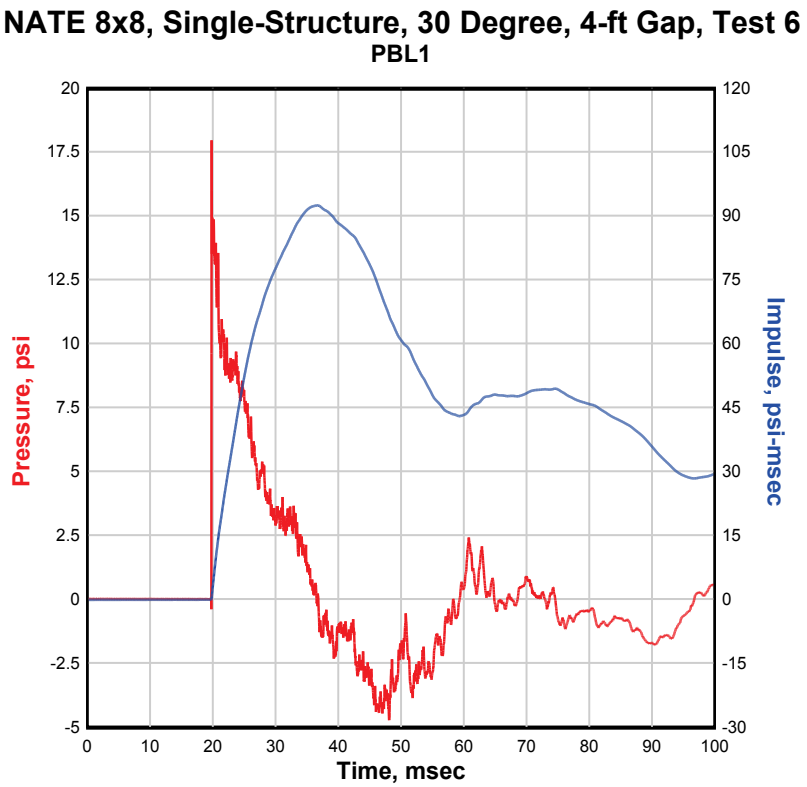
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
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70
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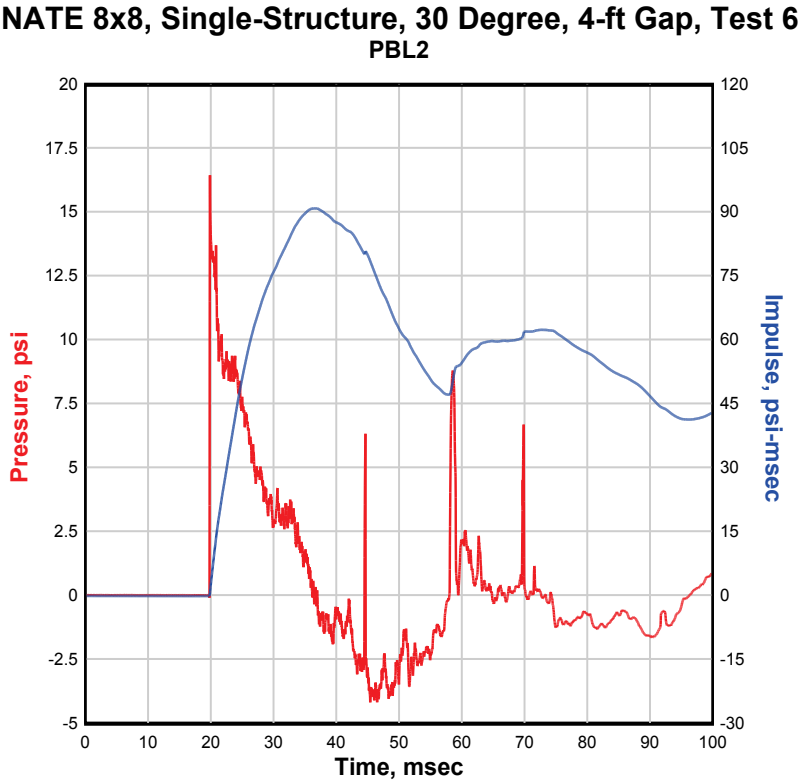
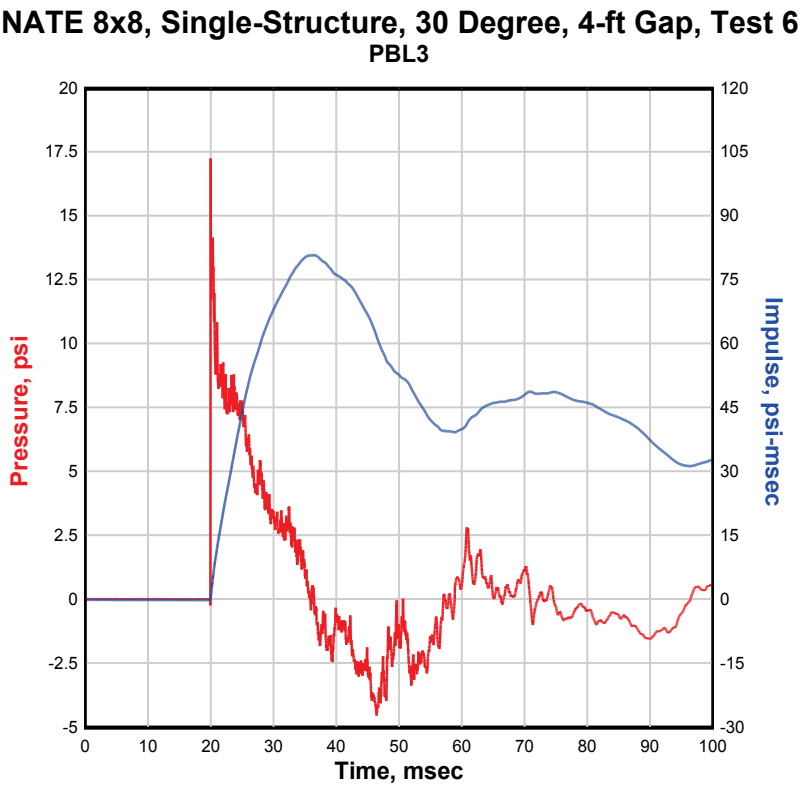
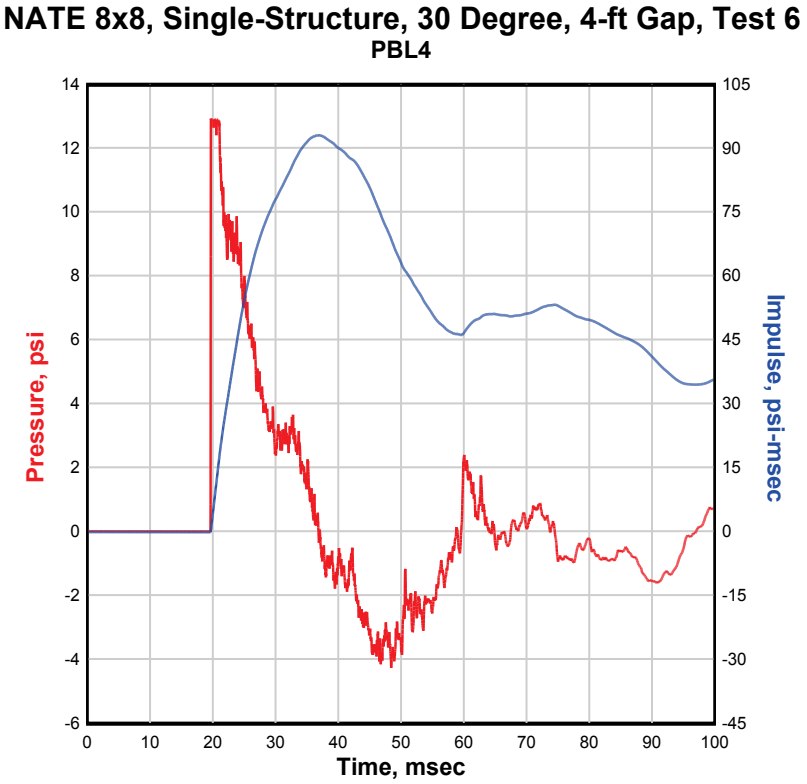
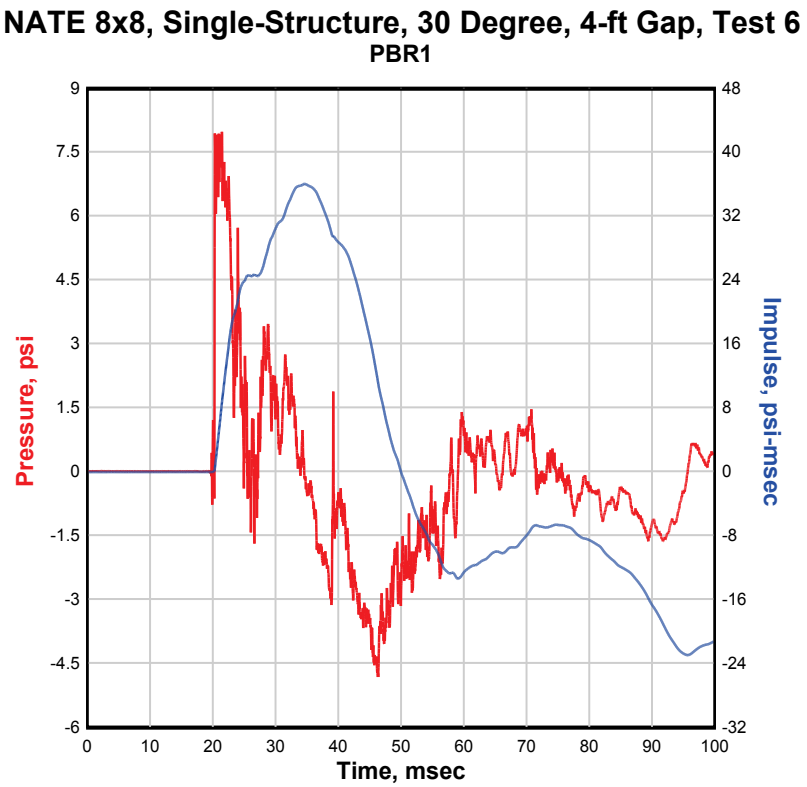
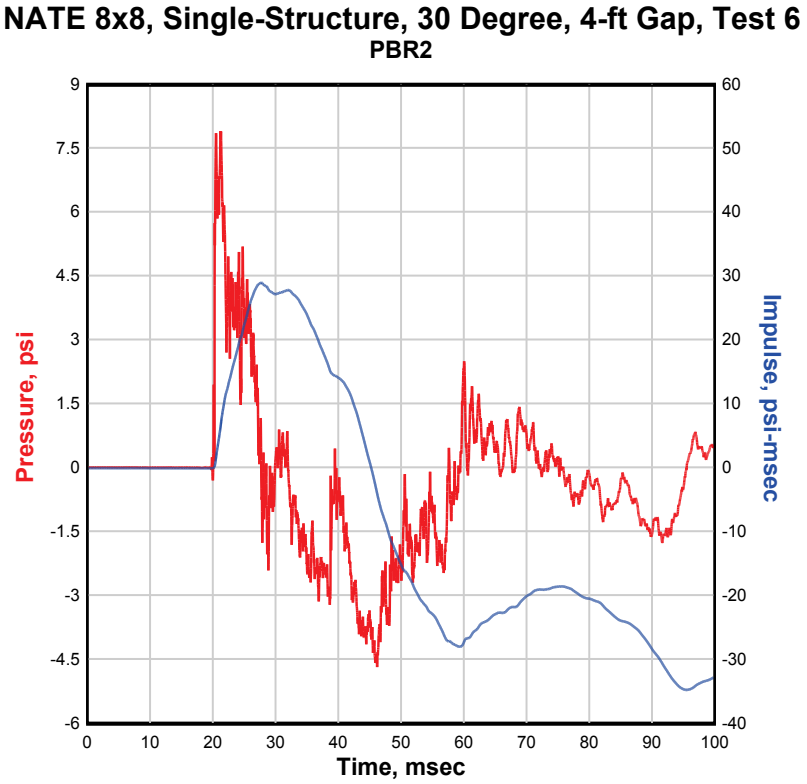
90
100

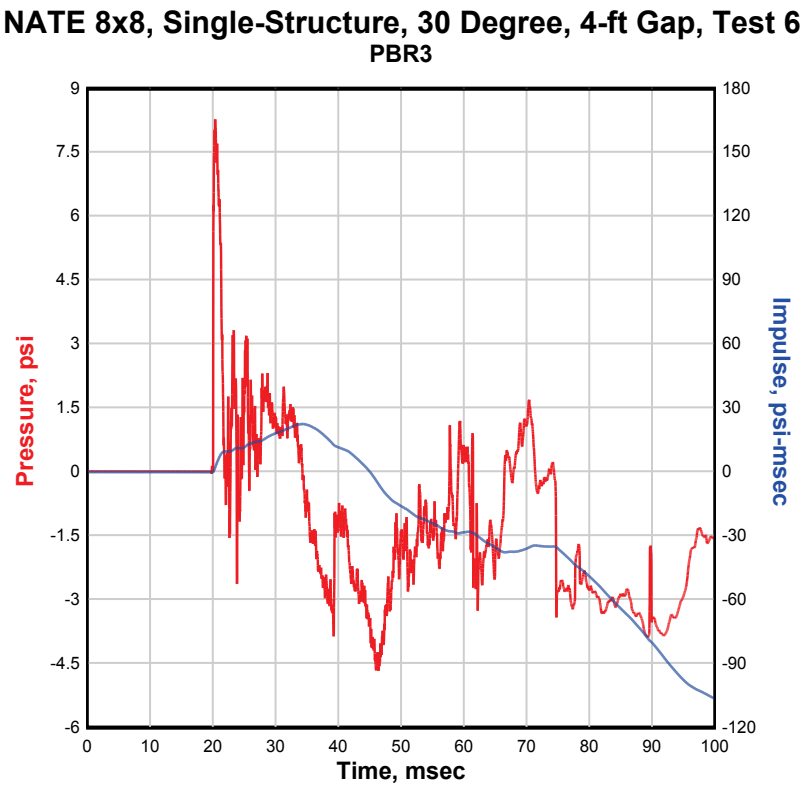

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

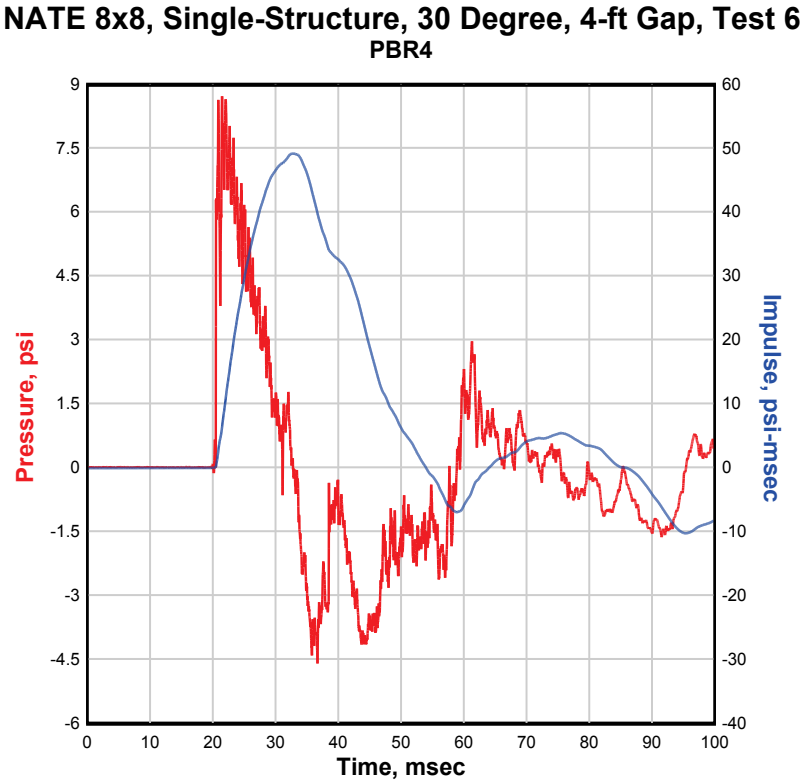

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
180
150
120
90
60
30
0
-30
-60
-90
-120
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
20
10
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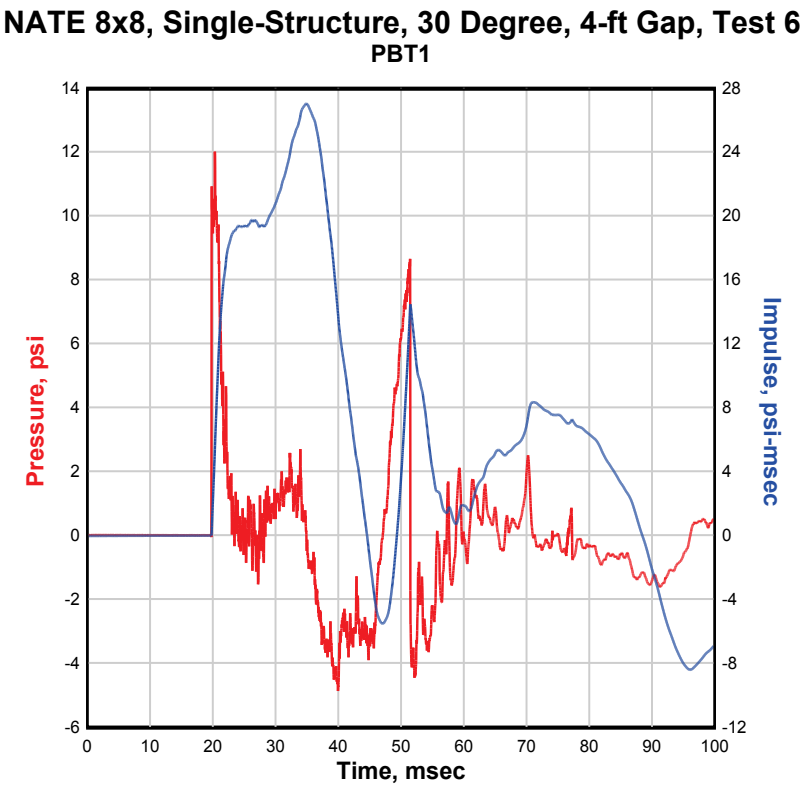
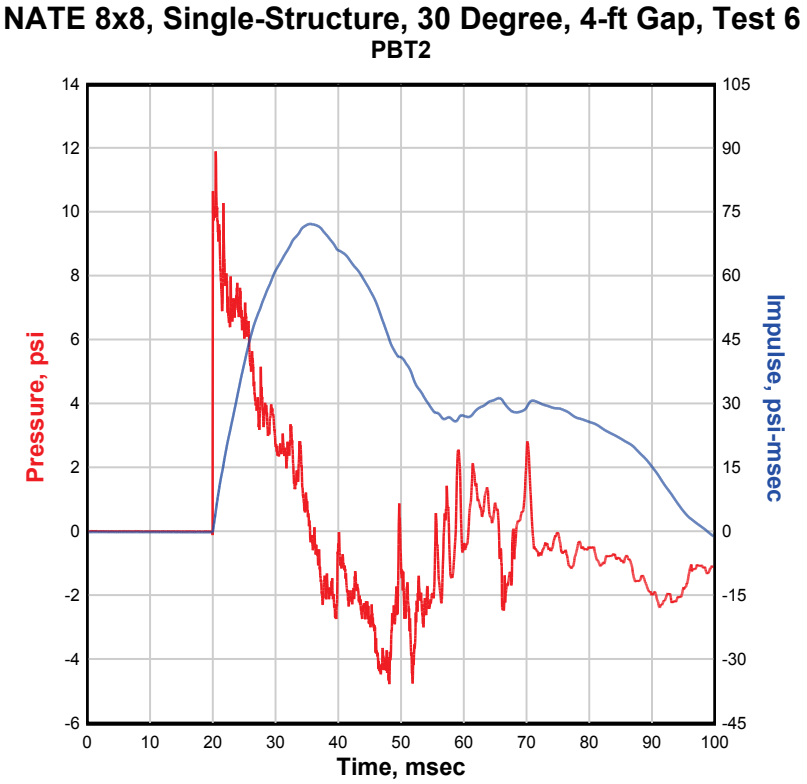
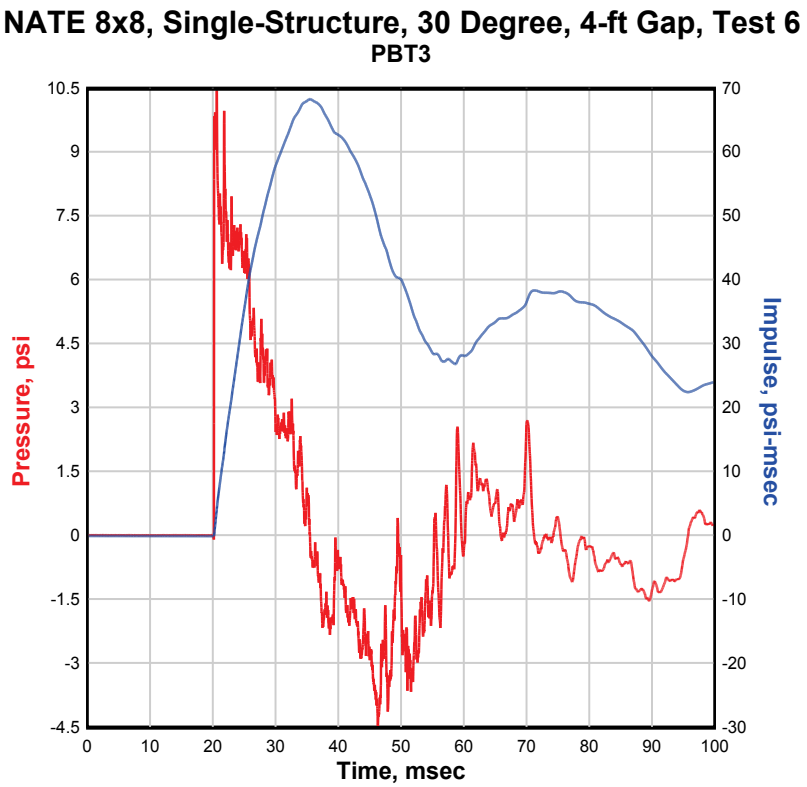
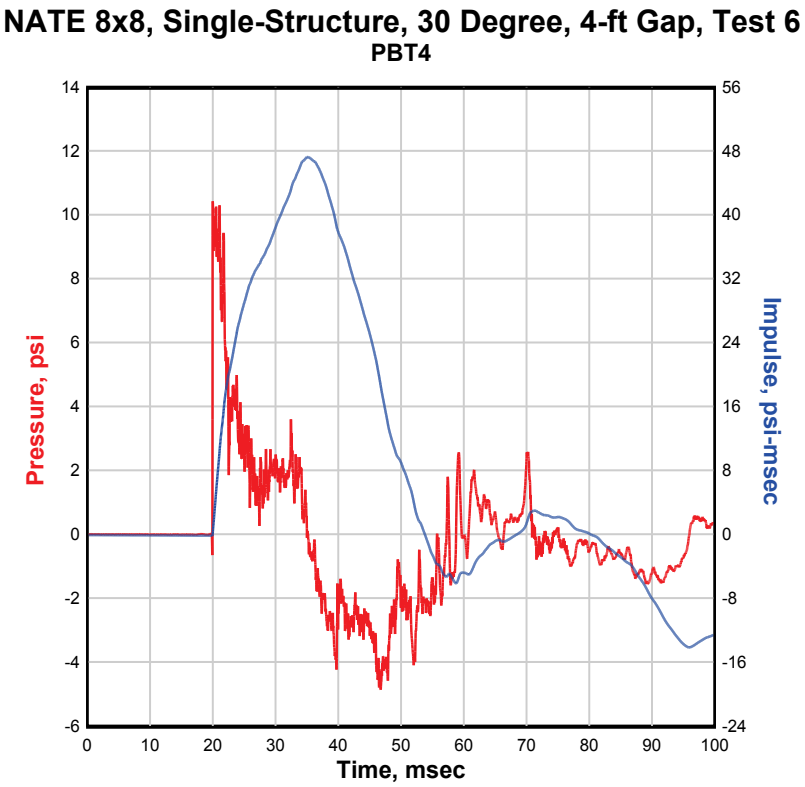
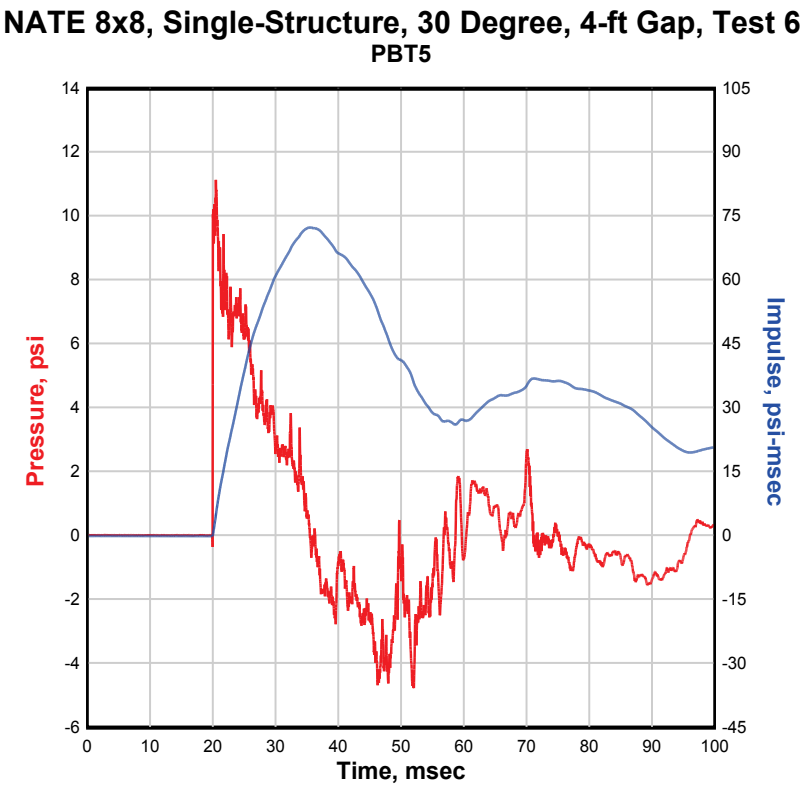
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100

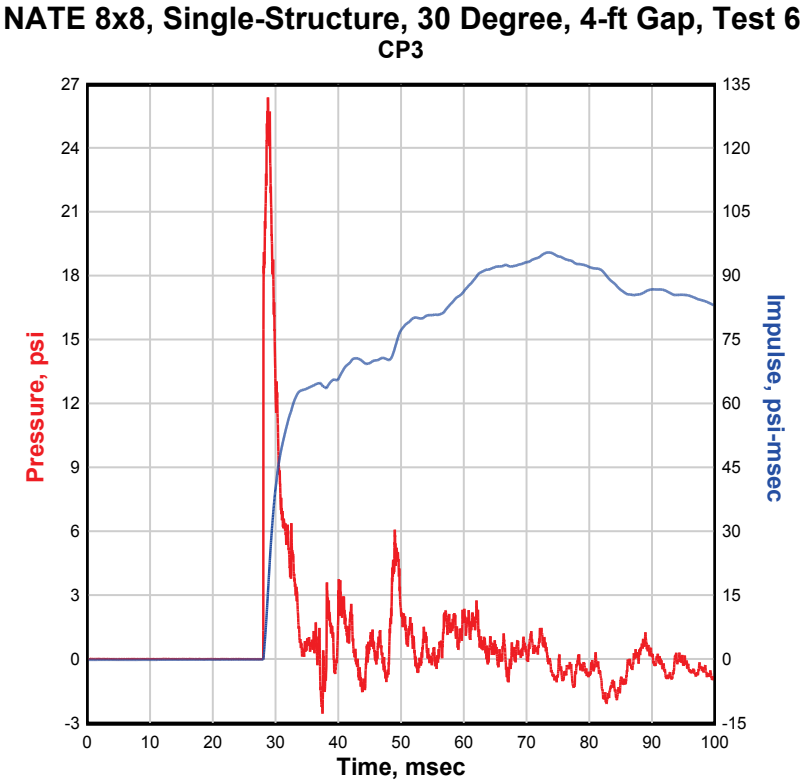

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
28
24
20
16
12
8
4
0
-4
-8
-12
0
10
20
30
40
50
60
70
80
90
100

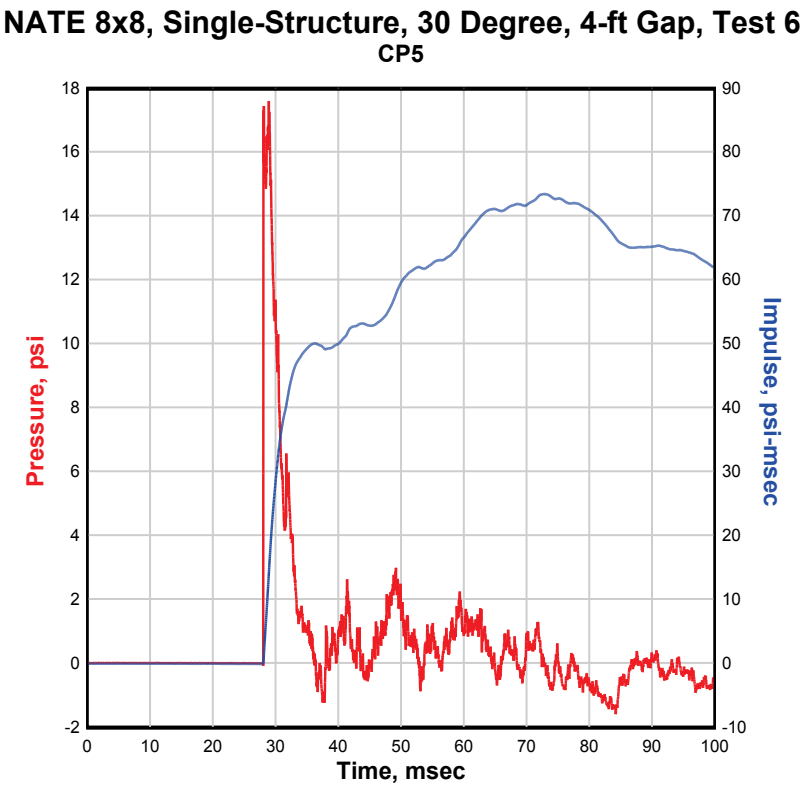

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

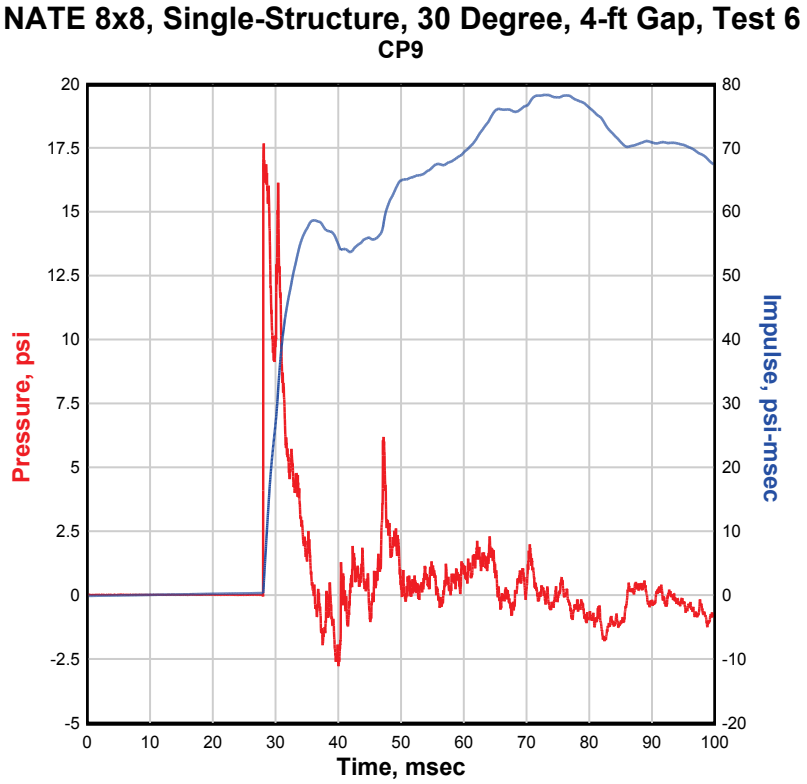

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

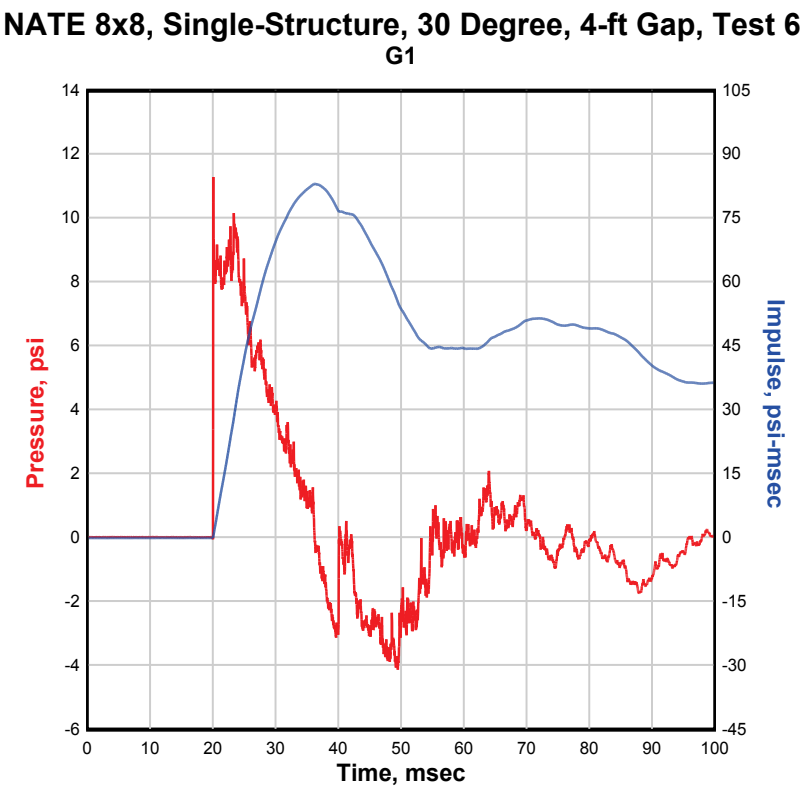

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

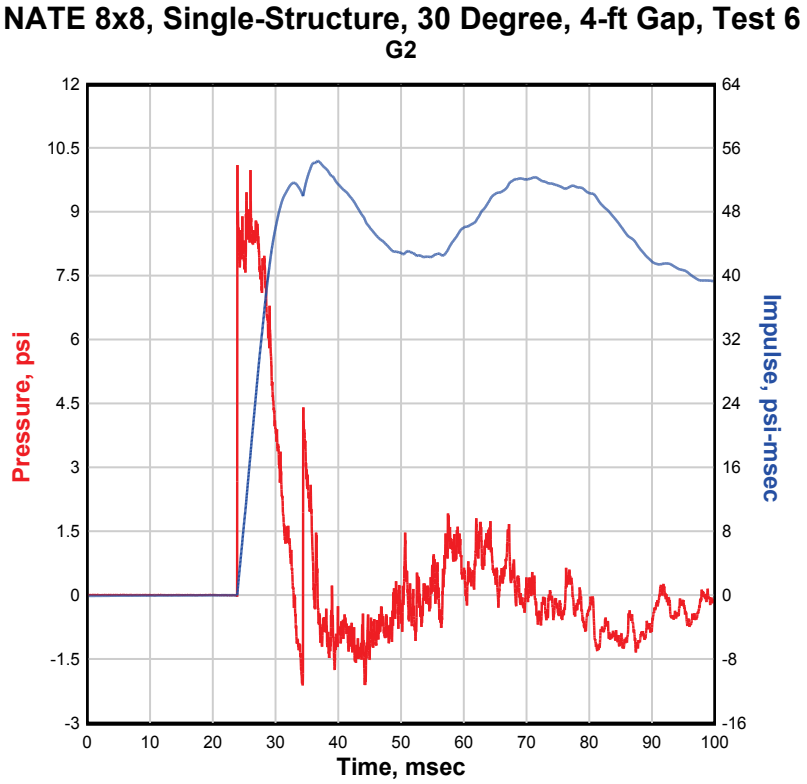

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

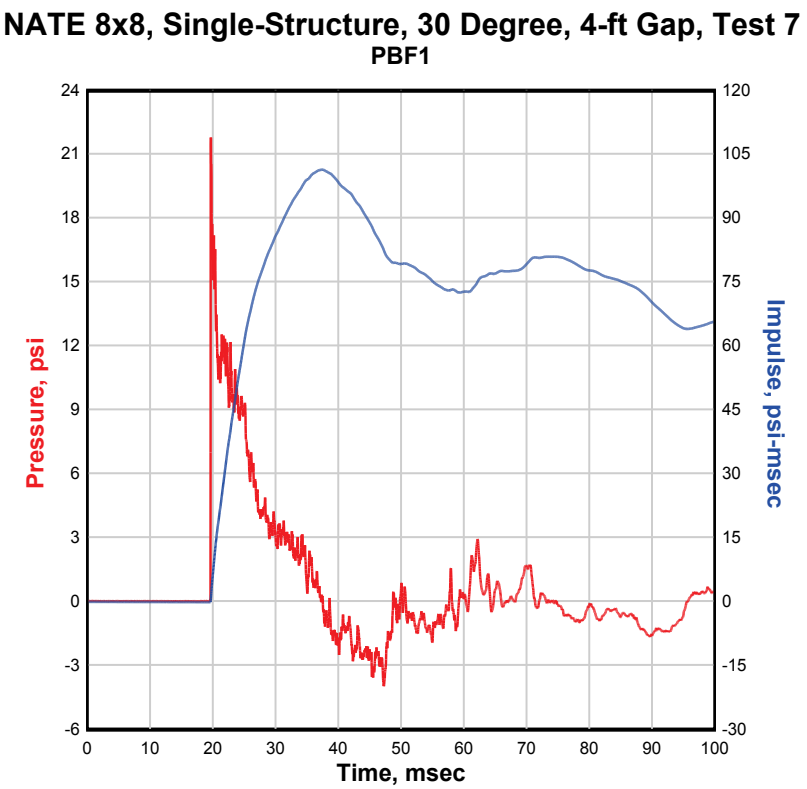

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

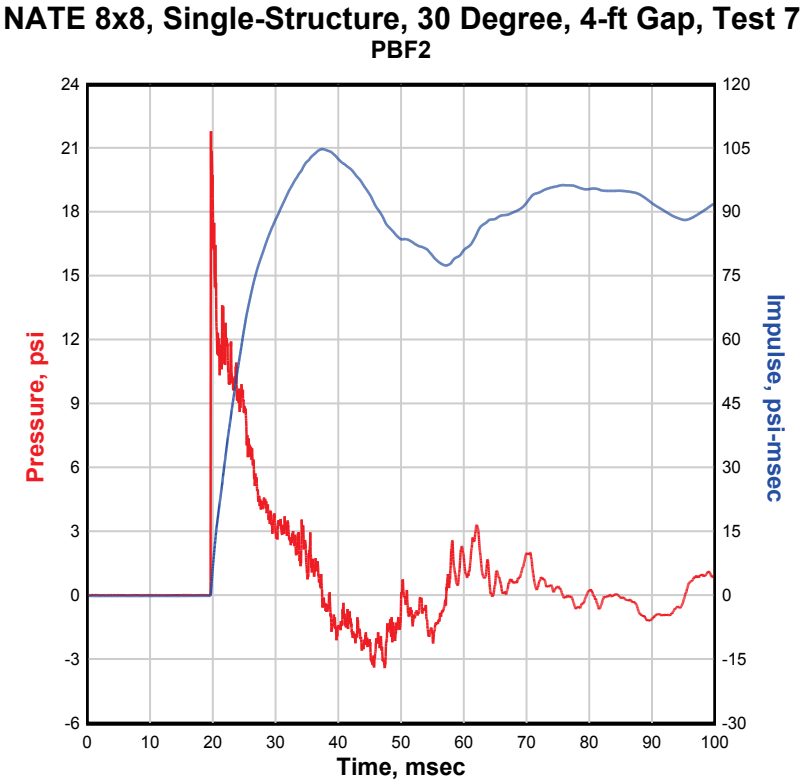

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
18
16
14
12
10
8
6
4
2
0
-2
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

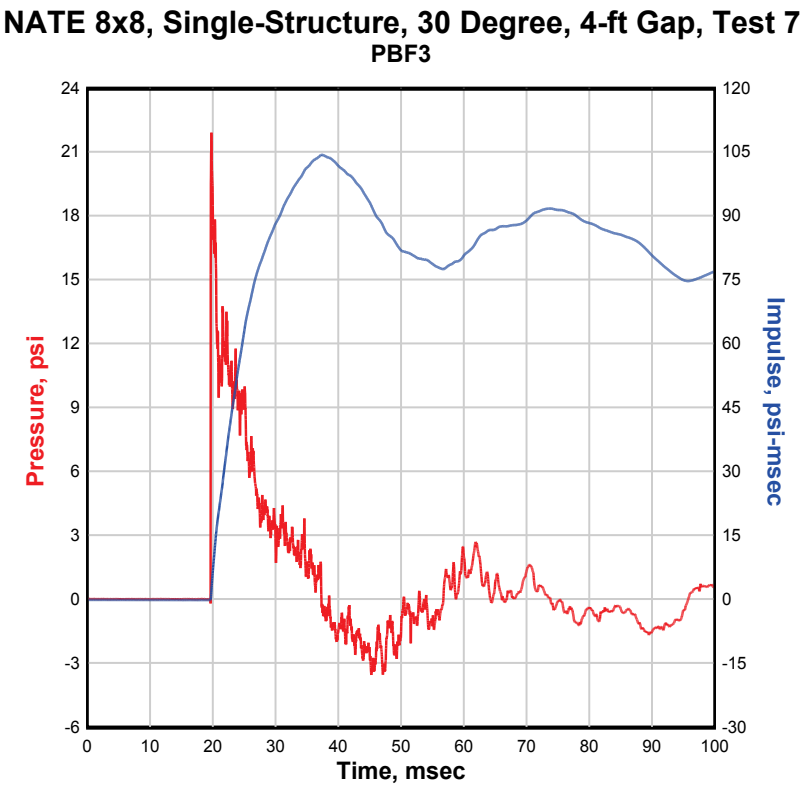

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
80
70
60
50
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100

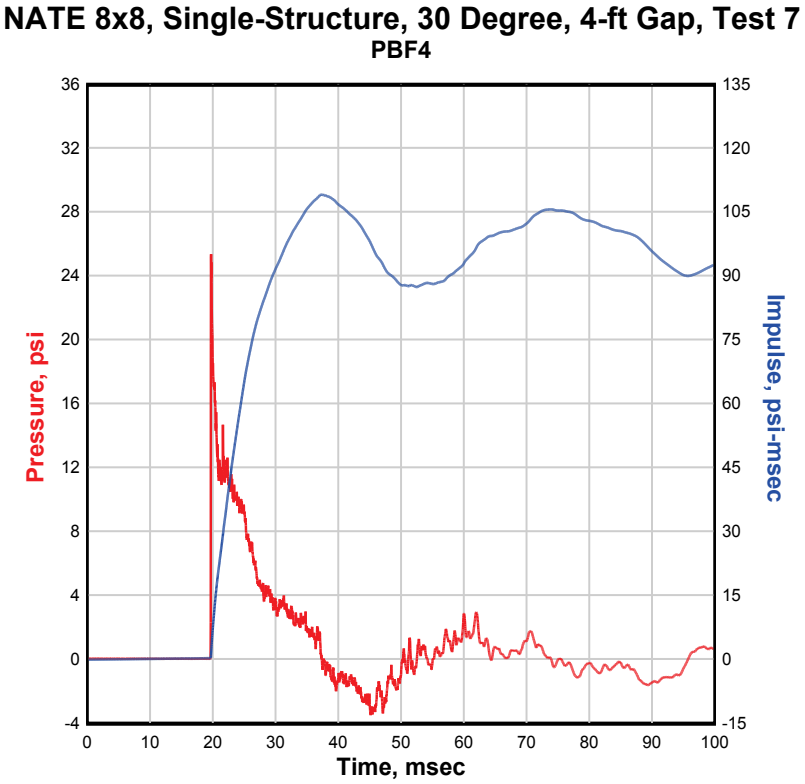

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
G1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

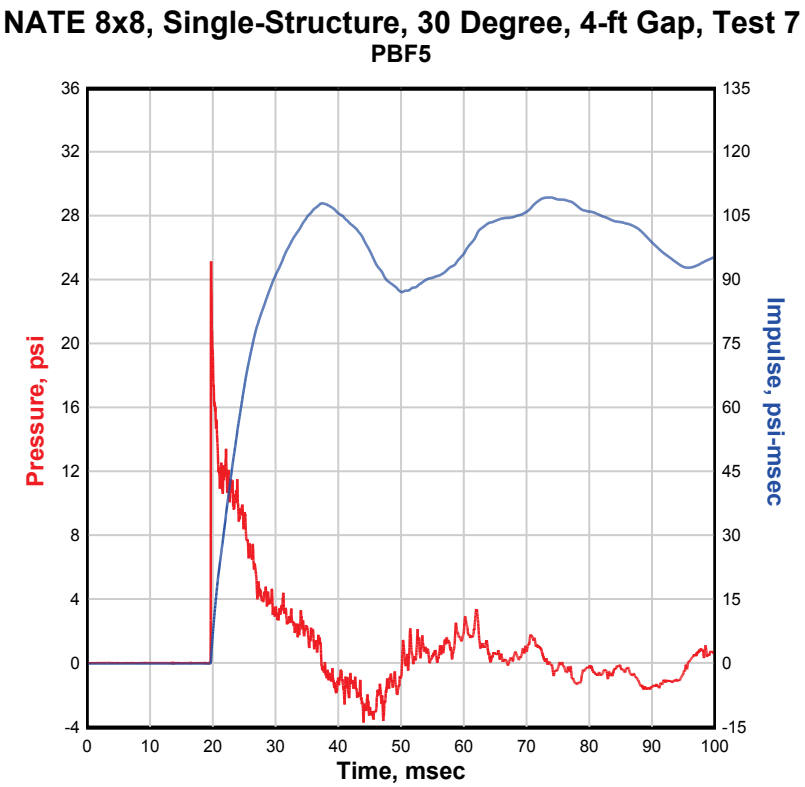

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 6
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

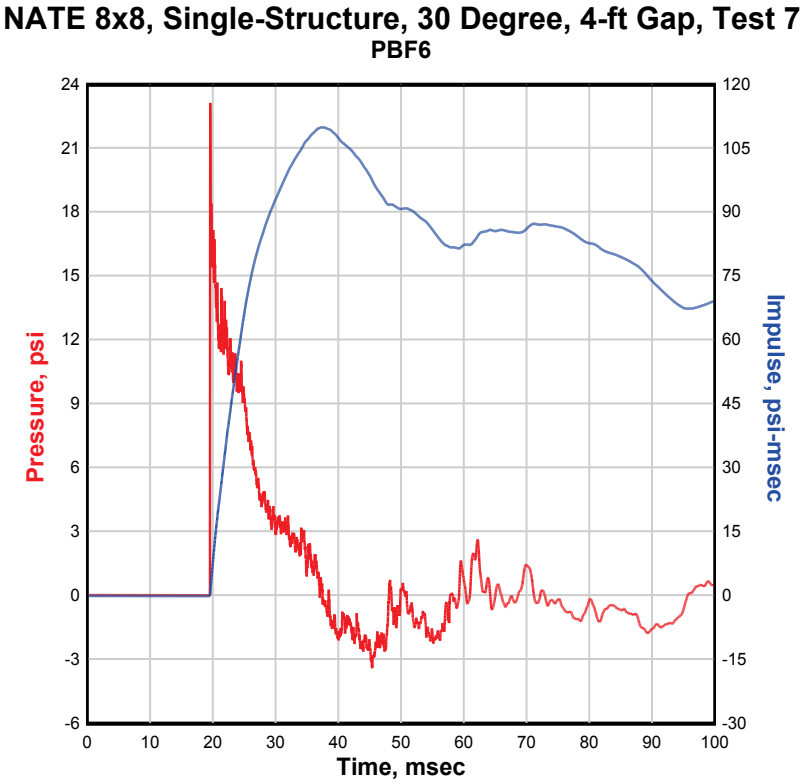

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

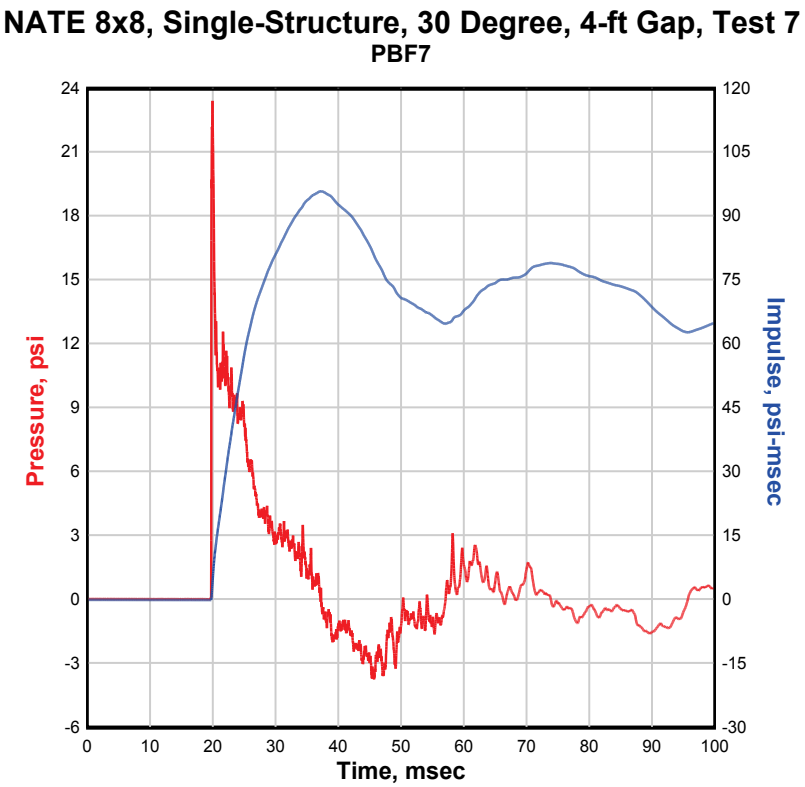

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

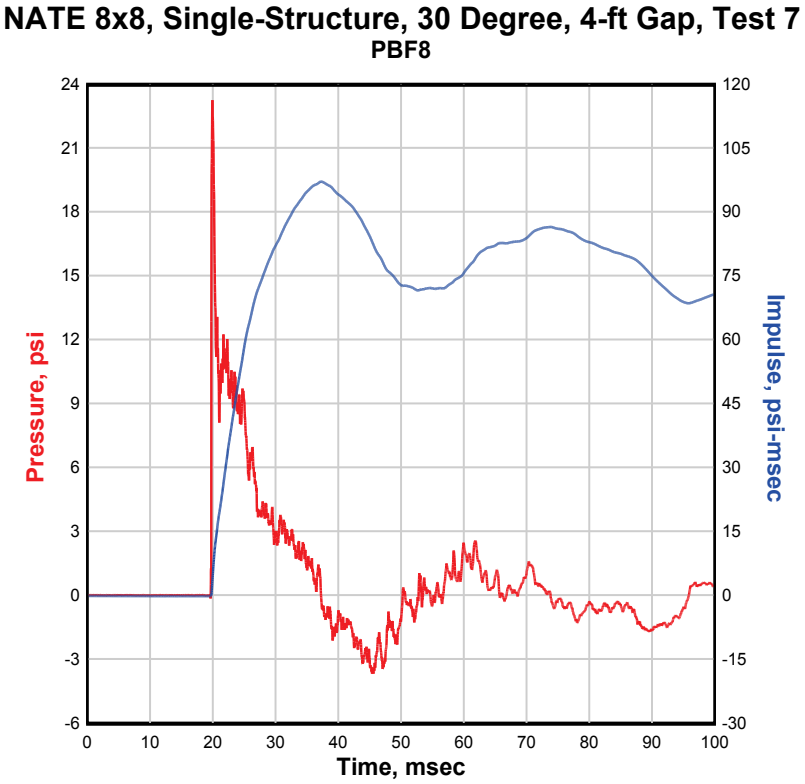

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

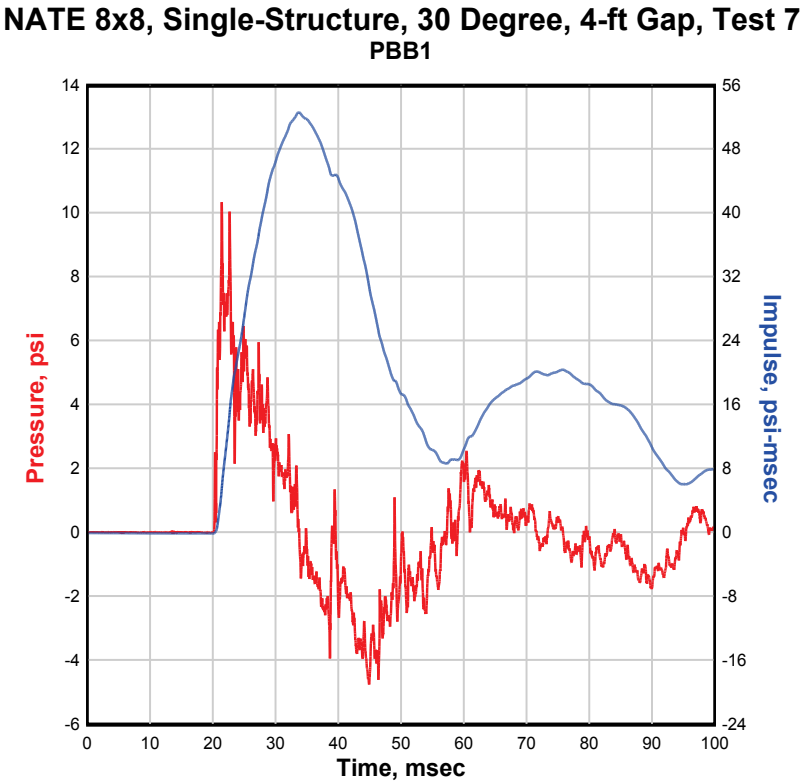

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

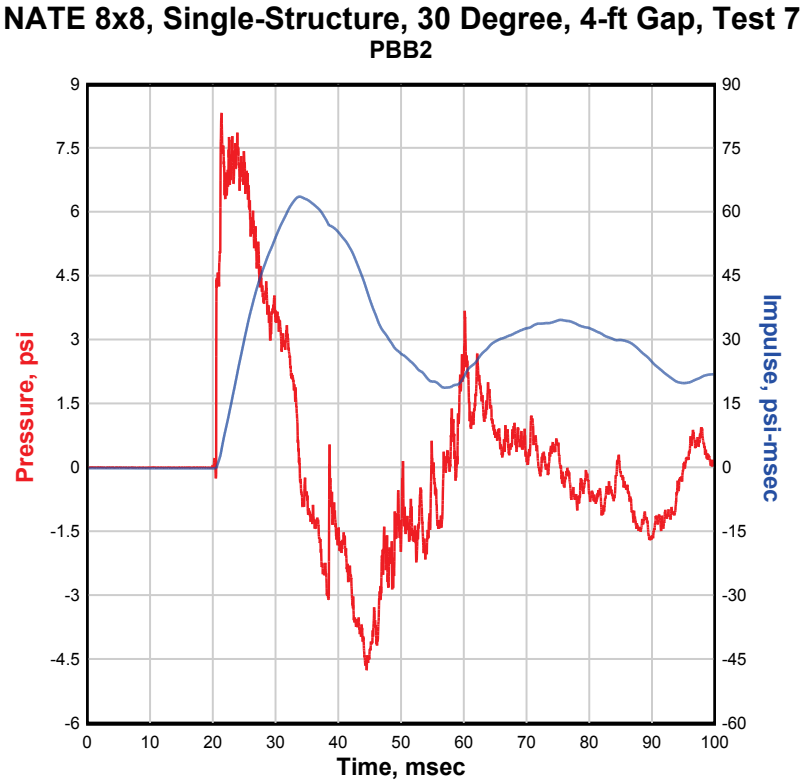

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

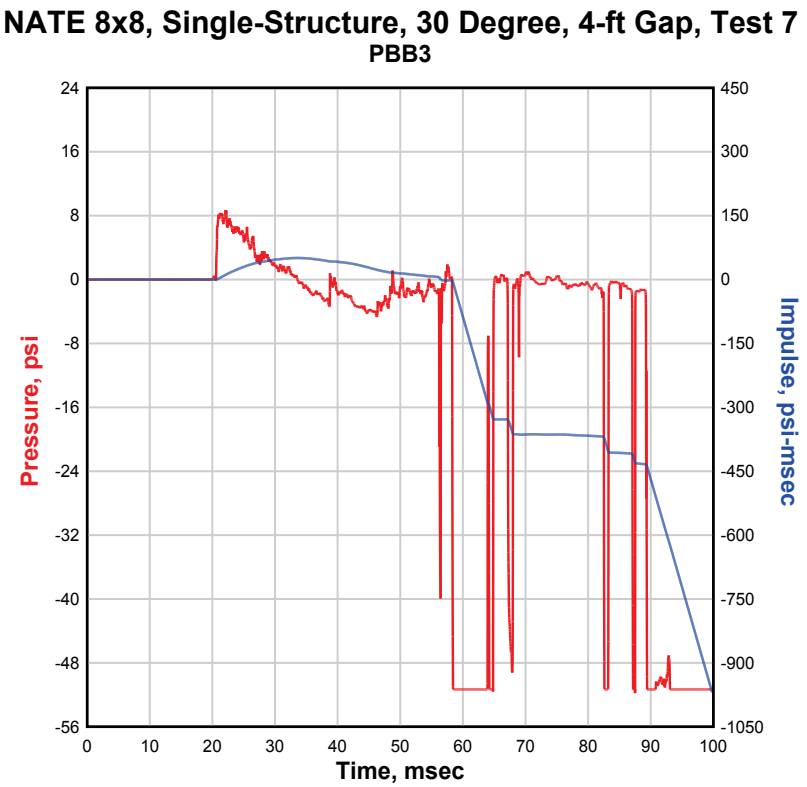

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

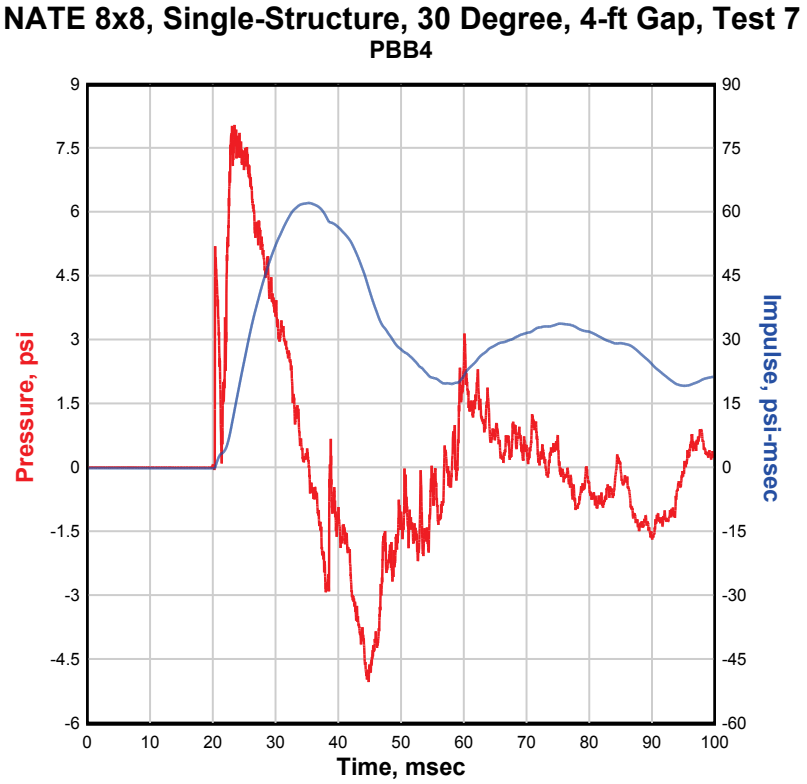

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

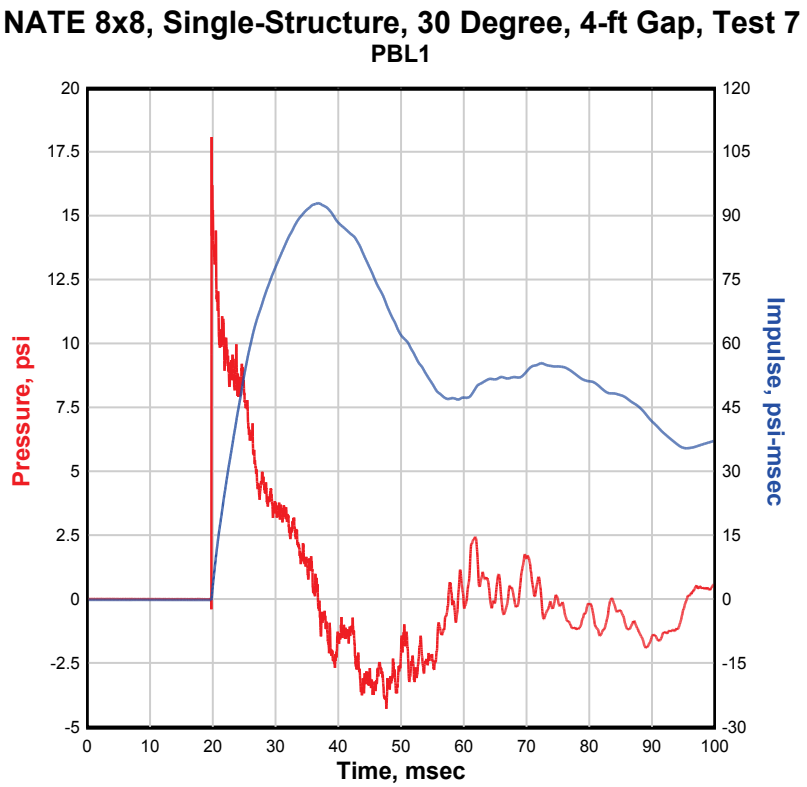

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

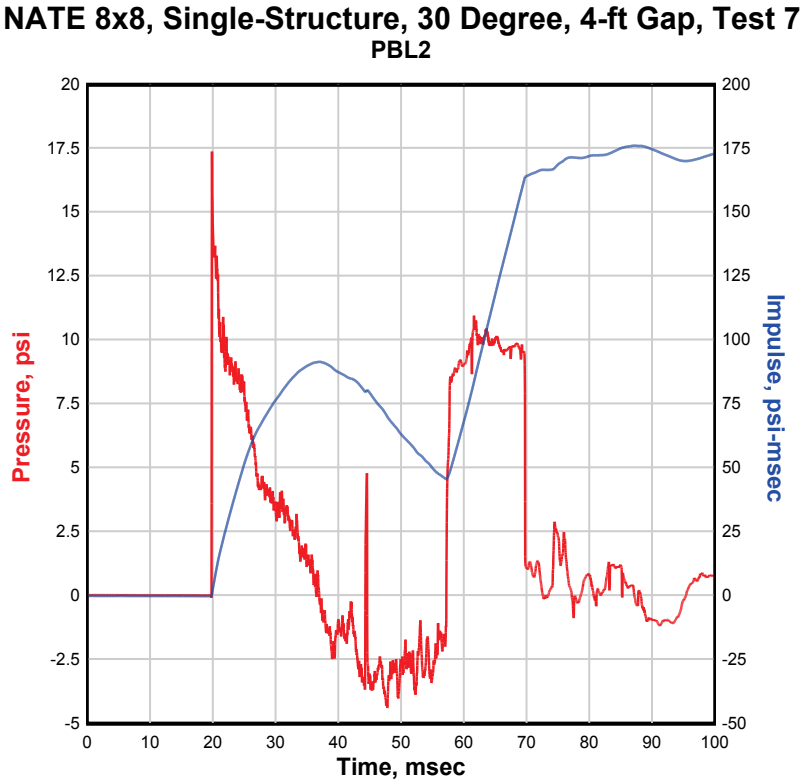

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

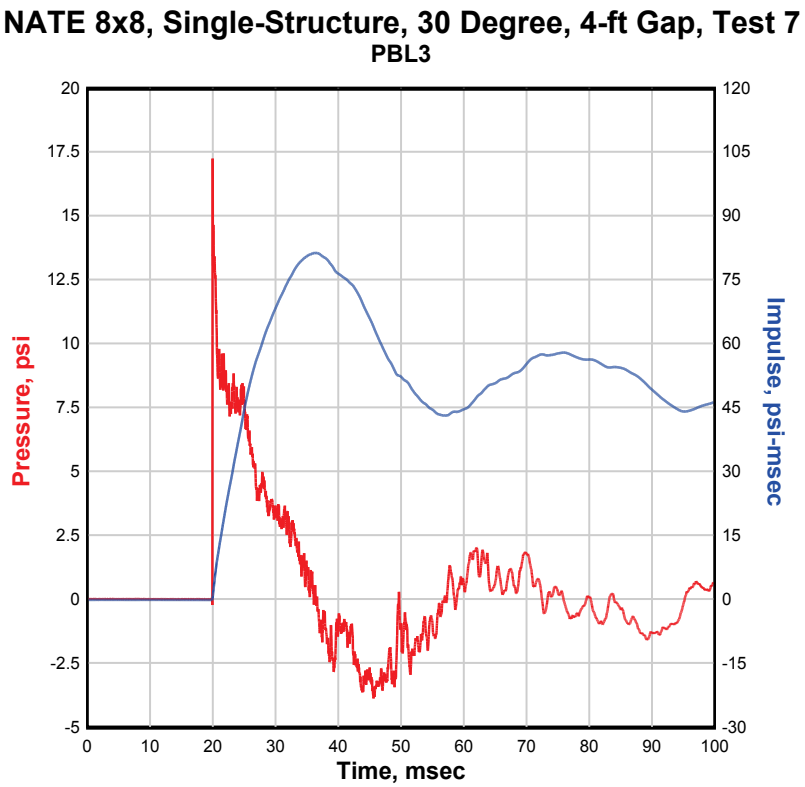

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

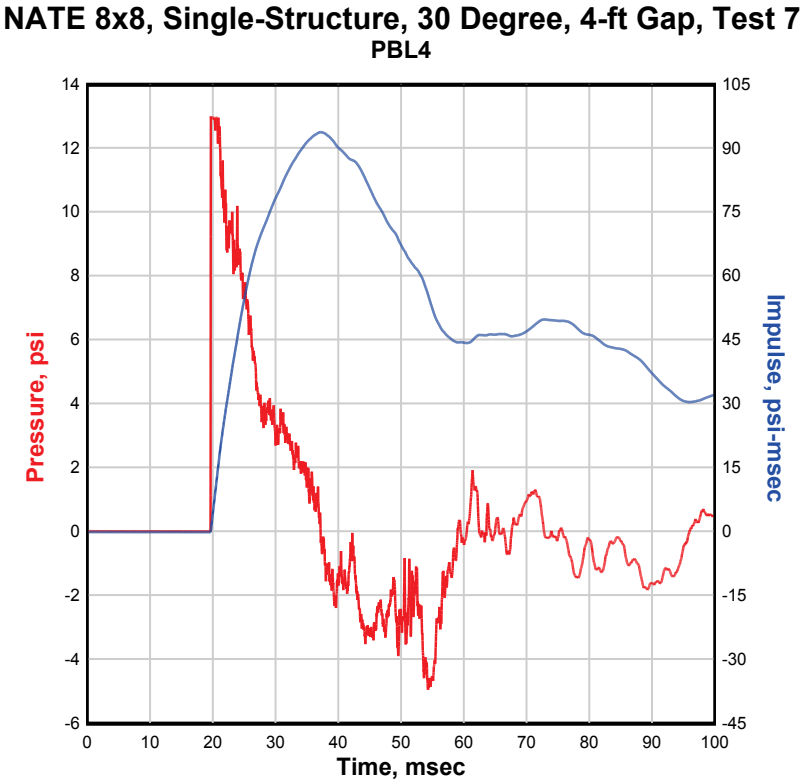

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
450
300
150
0
-150
-300
-450
-600
-750
-900
-1050
0
10
20
30
40
50
60
70
80
90
100

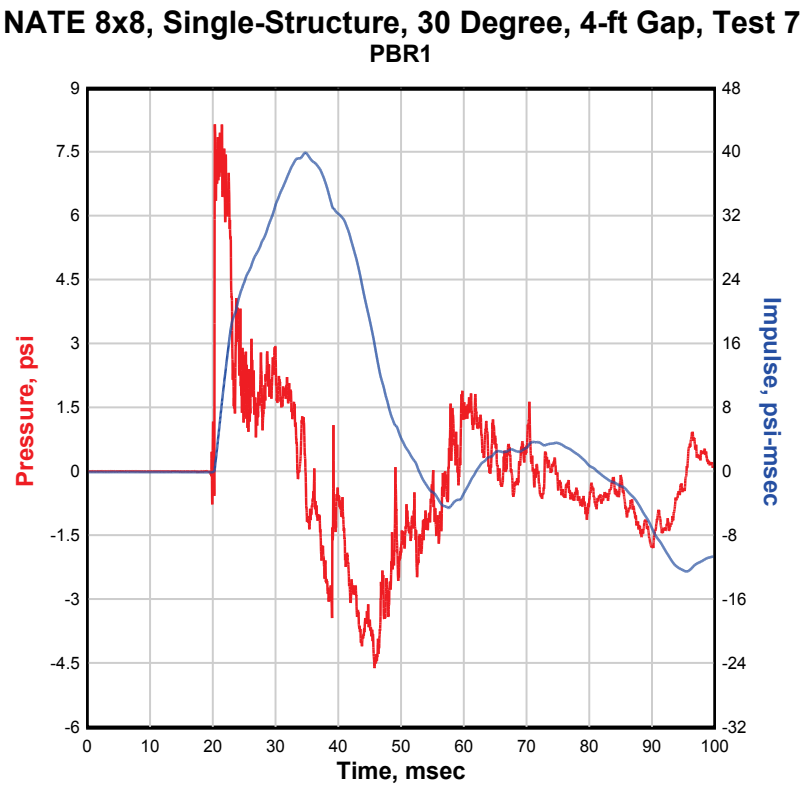

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

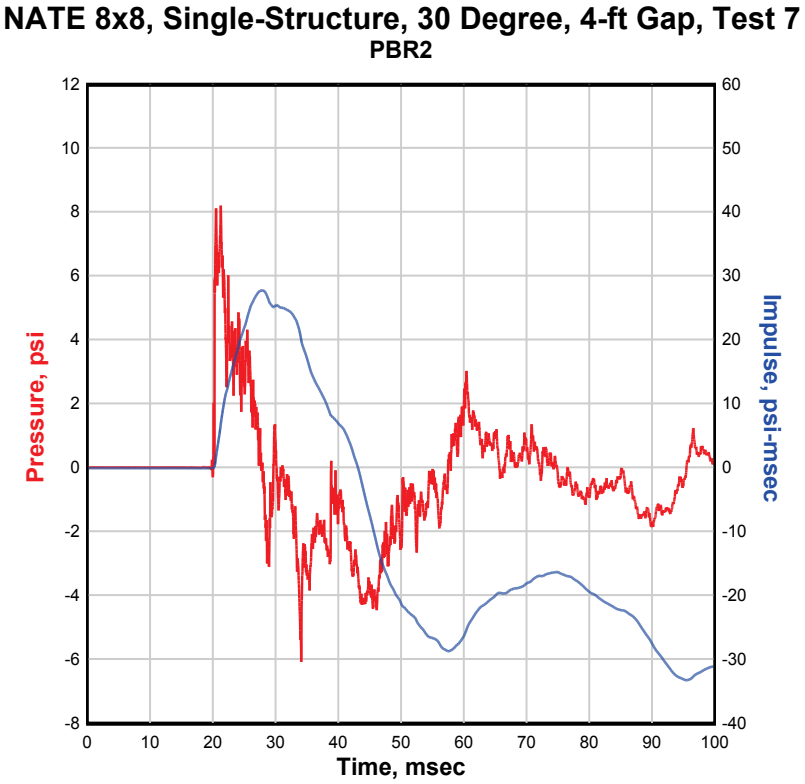

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

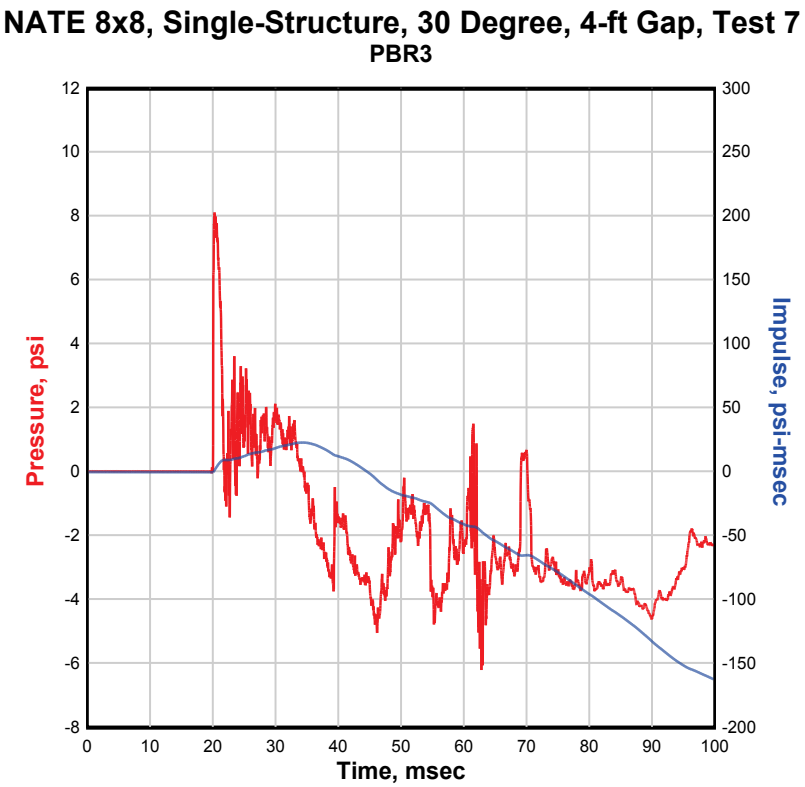

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
200
175
150
125
100
75
50
25
0
-25
-50
0
10
20
30
40
50
60
70
80
90
100

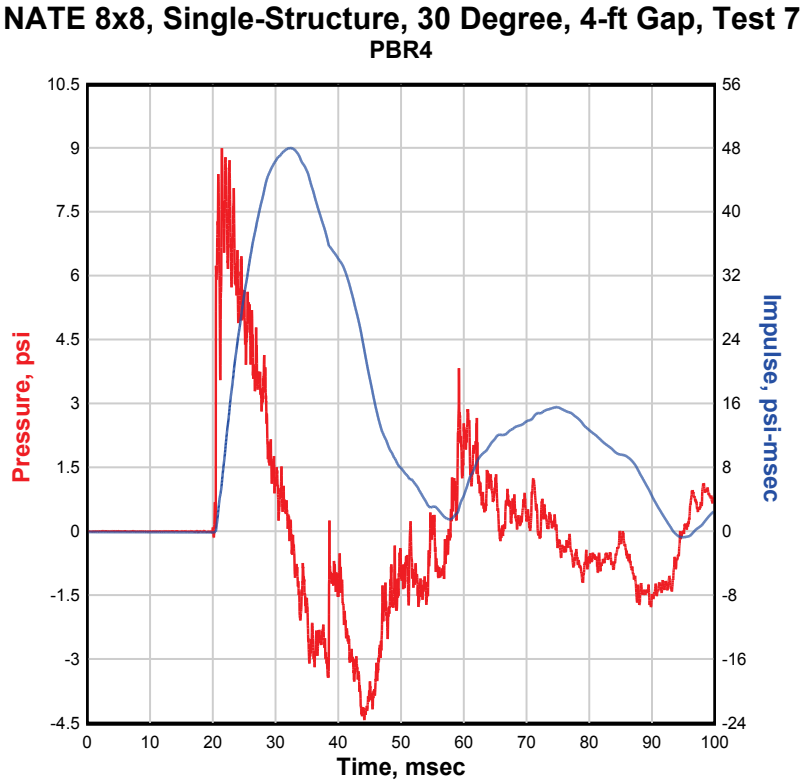

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

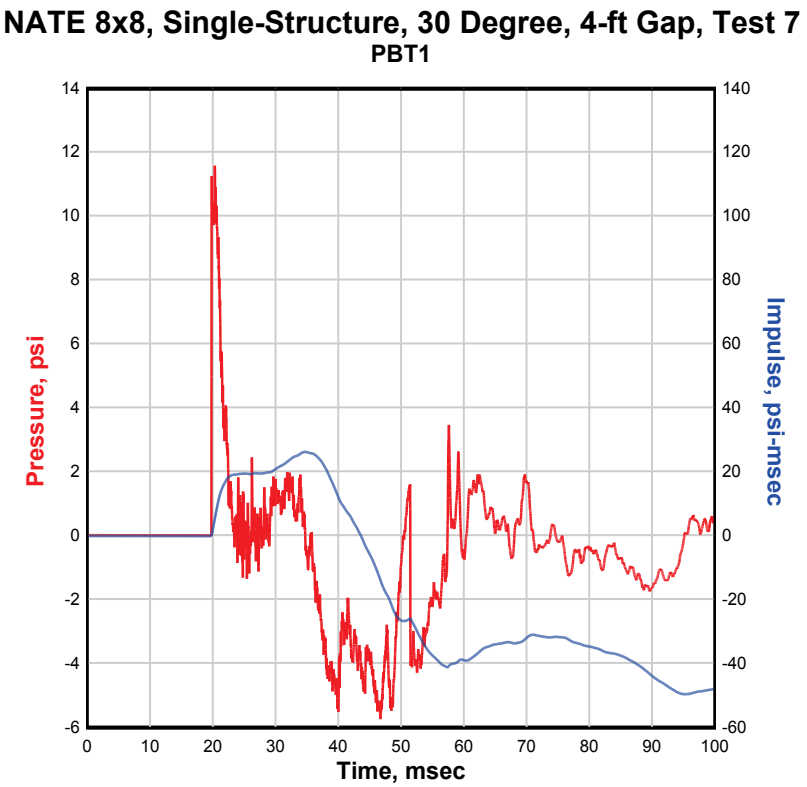

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

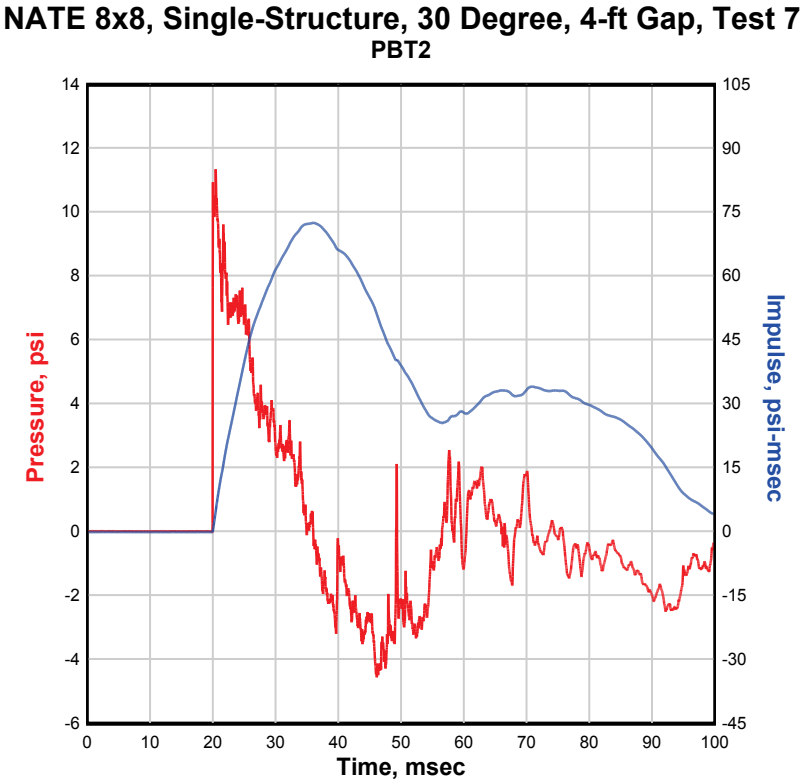

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100

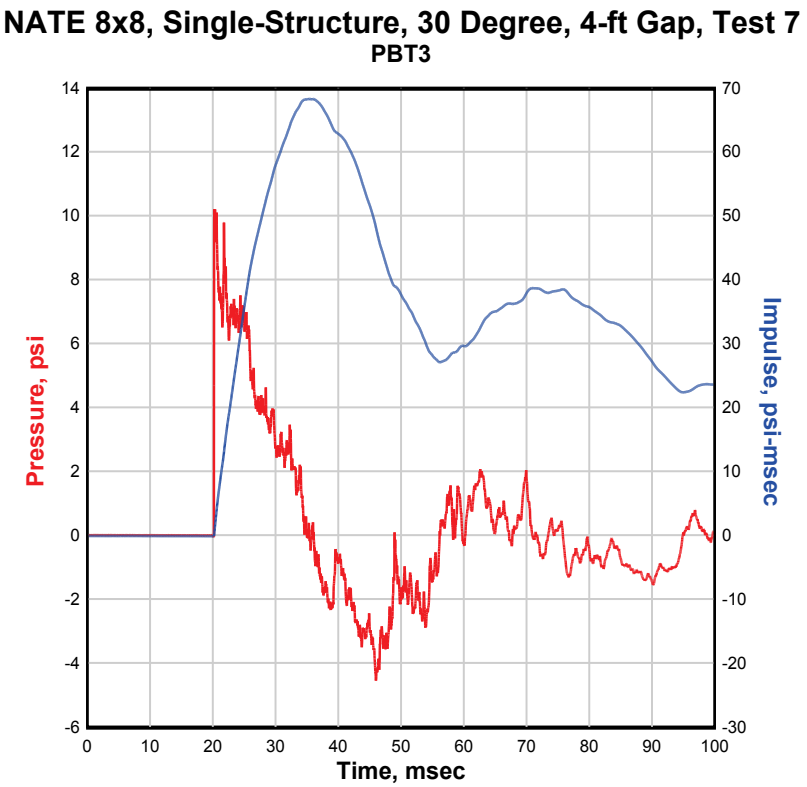

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100

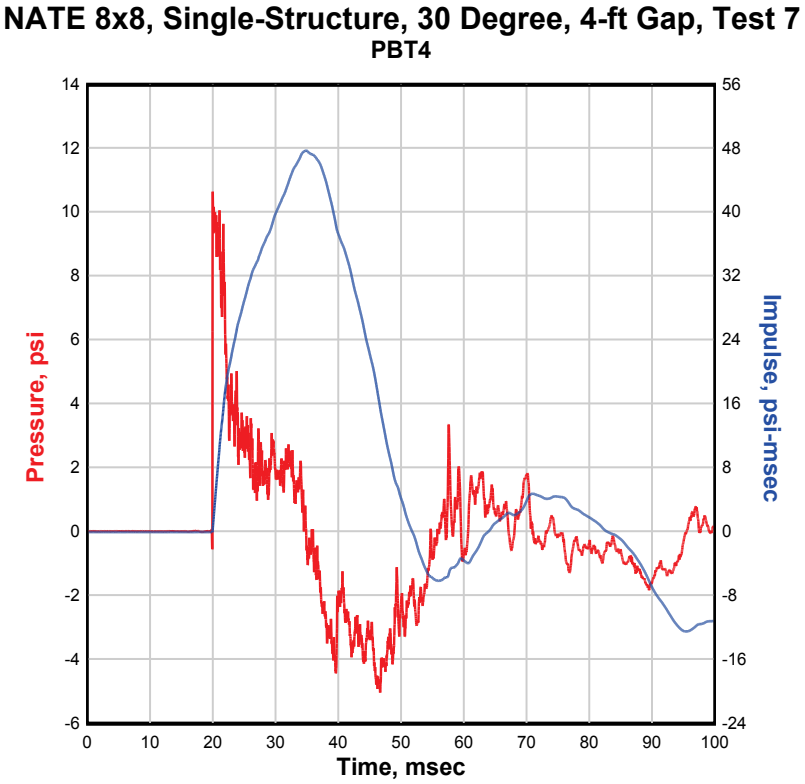

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
300
250
200
150
100
50
0
-50
-100
-150
-200
0
10
20
30
40
50
60
70
80
90
100

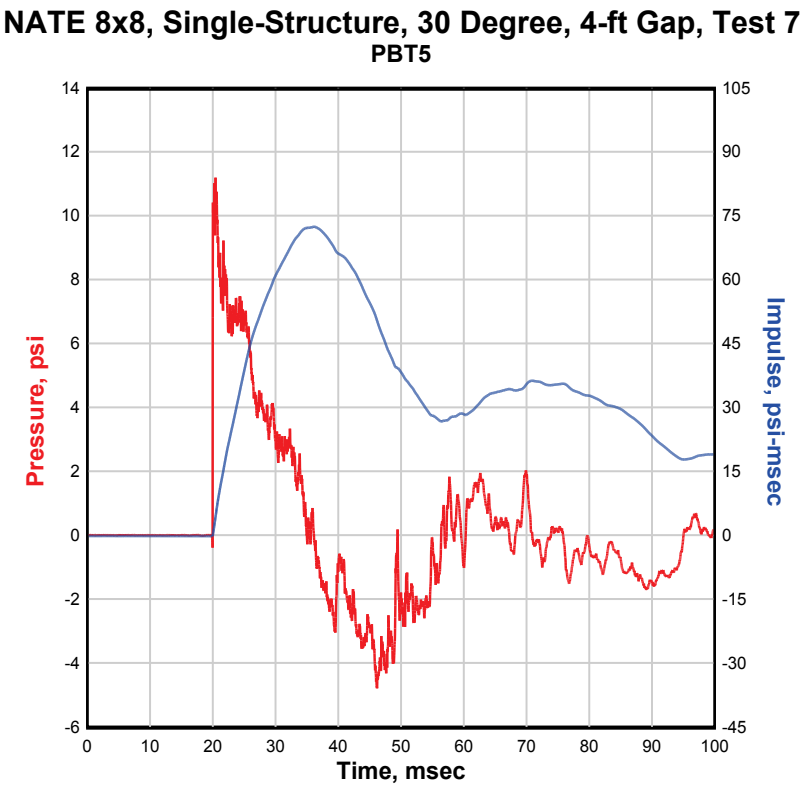

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

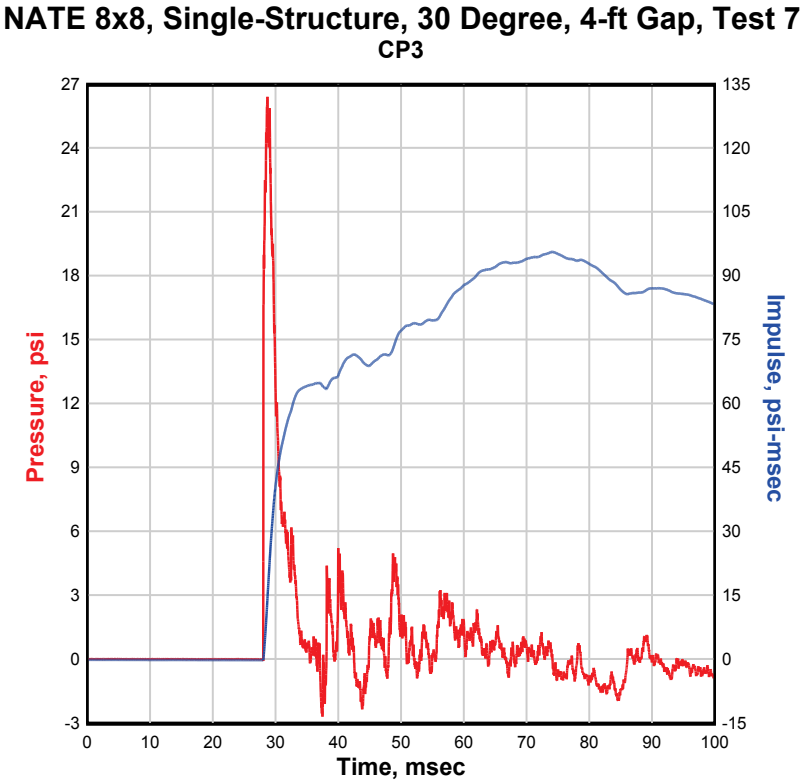

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
140
120
100
80
60
40
20
0
-20
-40
-60
0
10
20
30
40
50
60
70
80
90
100

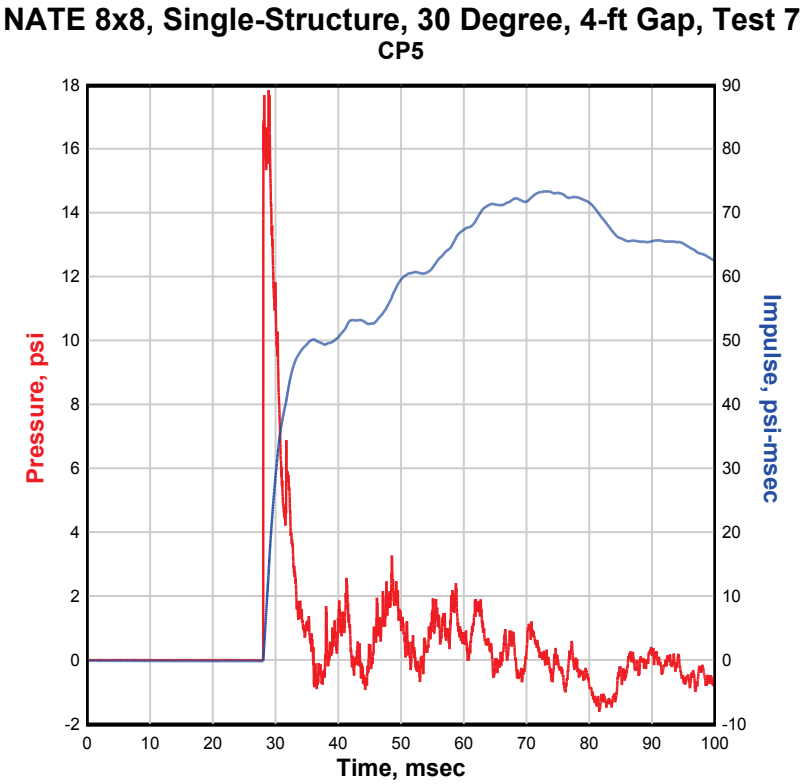

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

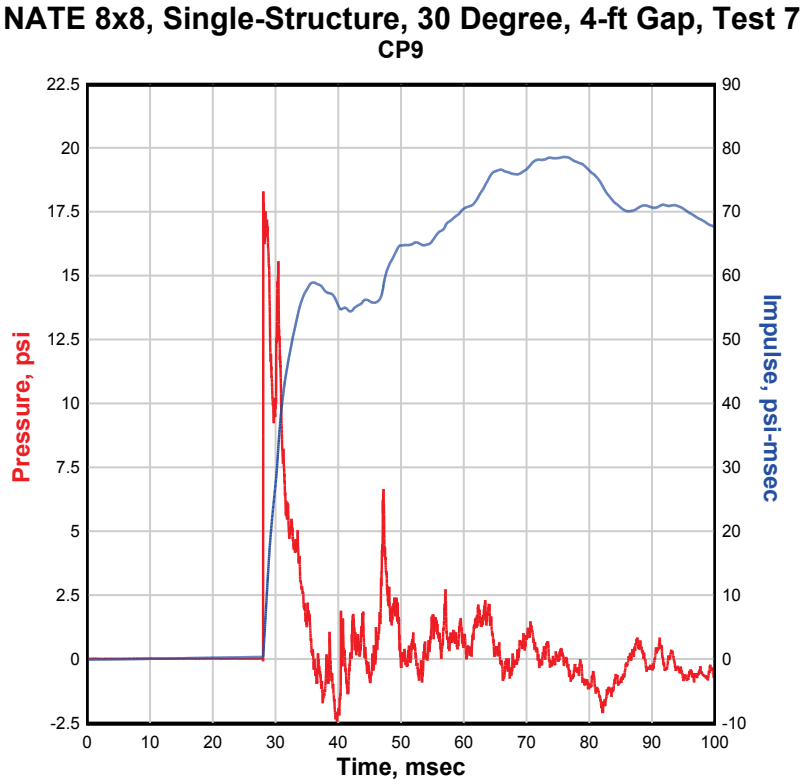

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

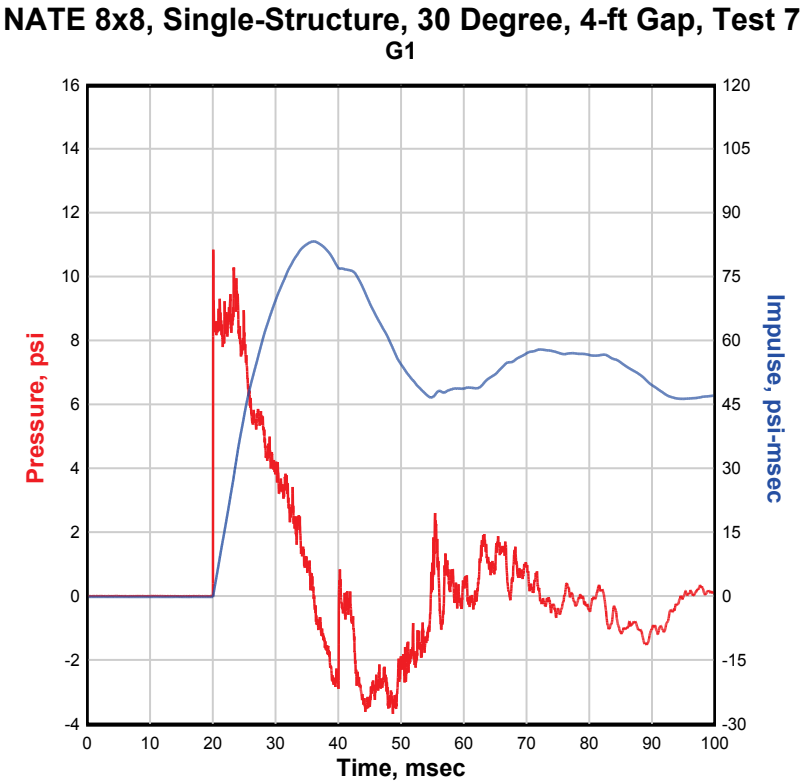

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

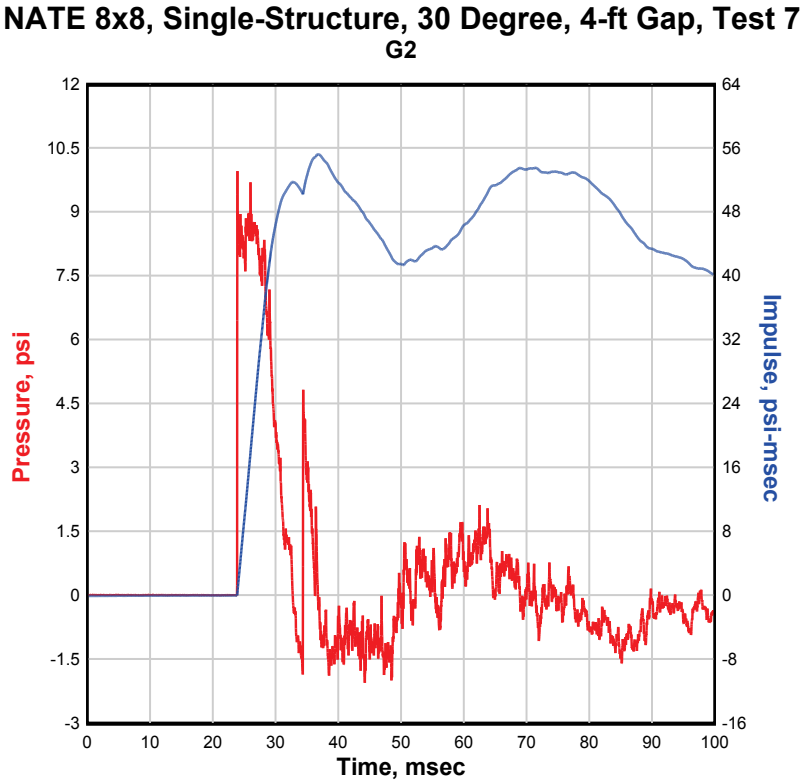

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

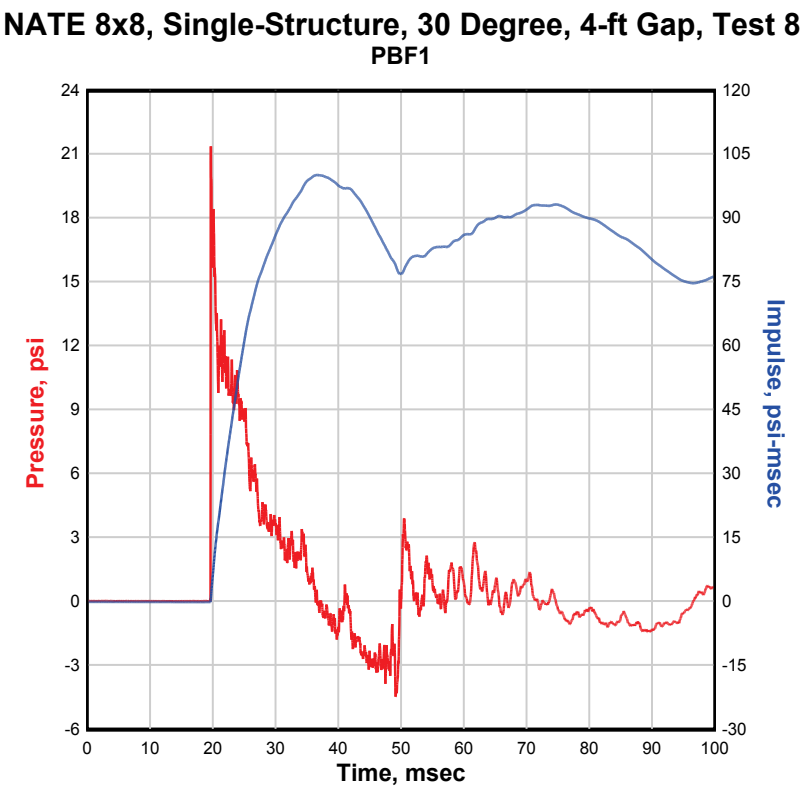

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

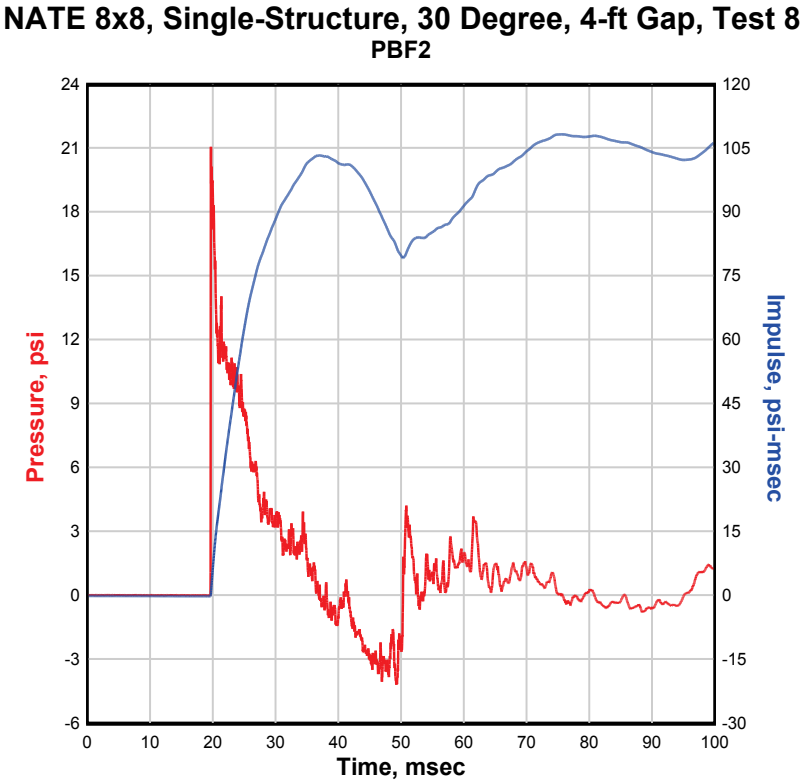

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
18
16
14
12
10
8
6
4
2
0
-2
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

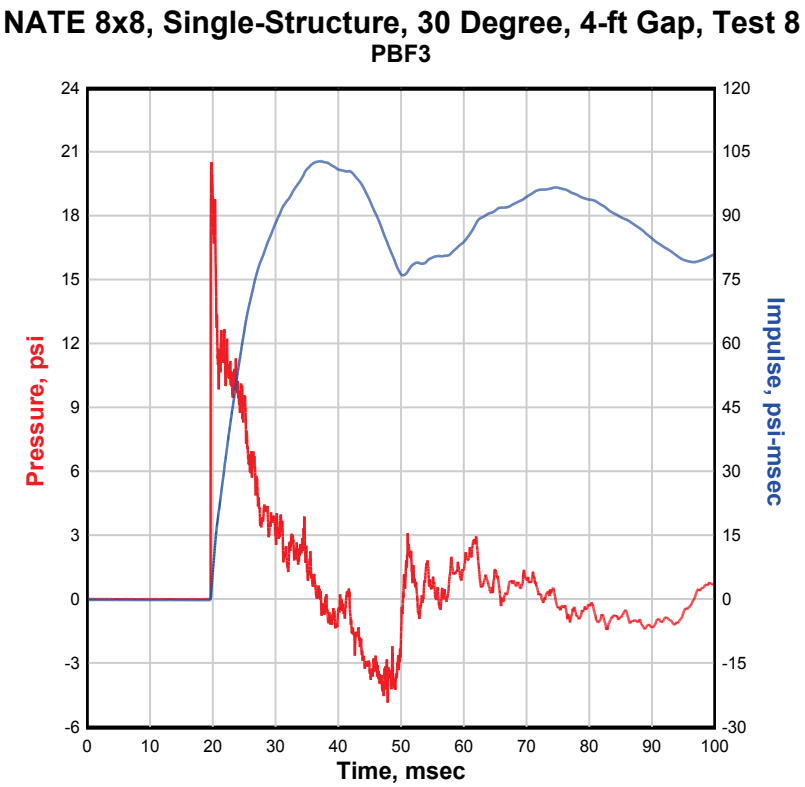

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

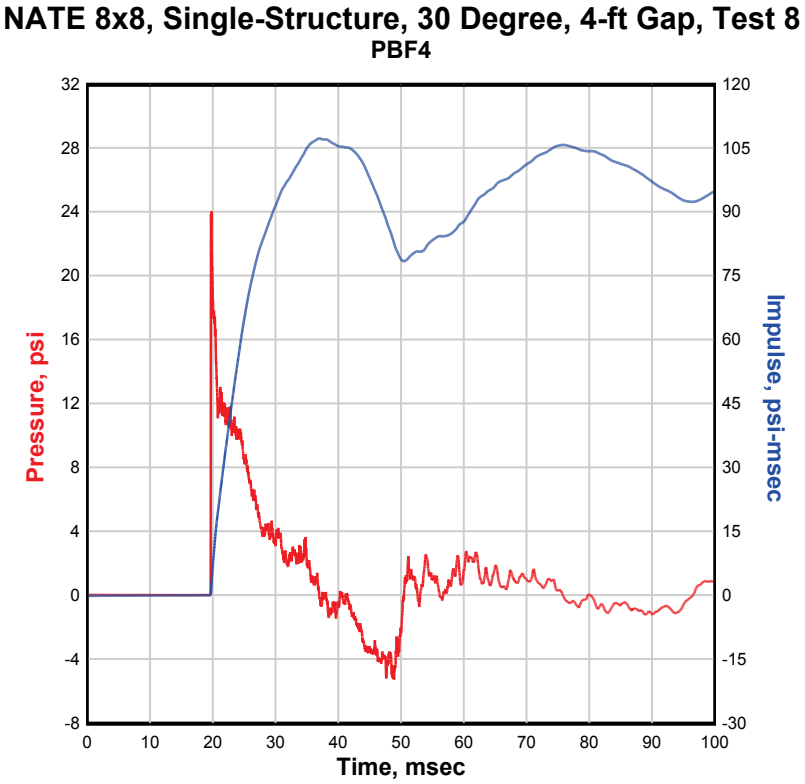

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
G1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

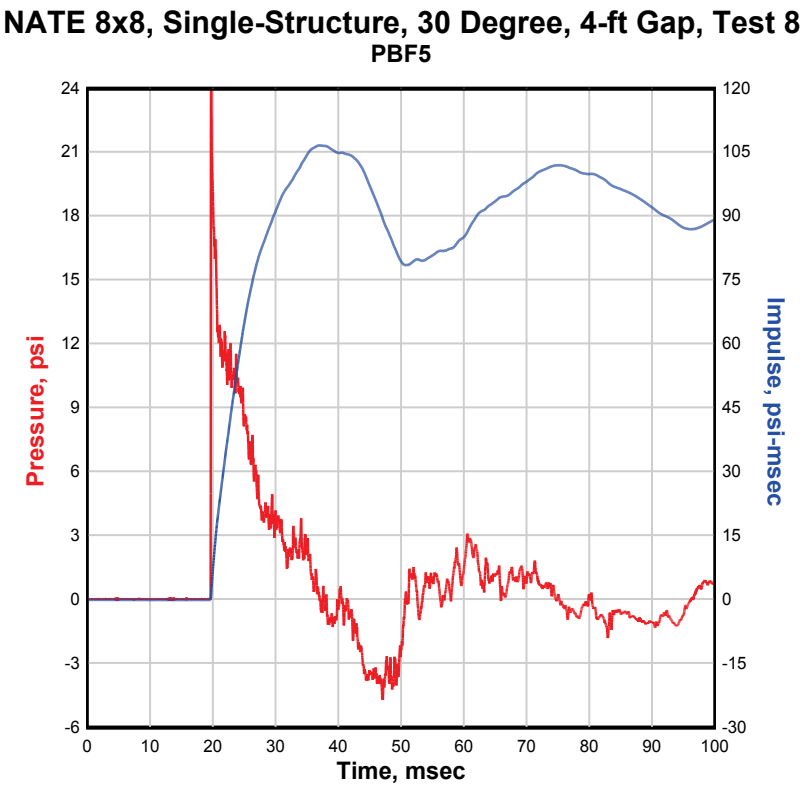

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 7
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
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30
40
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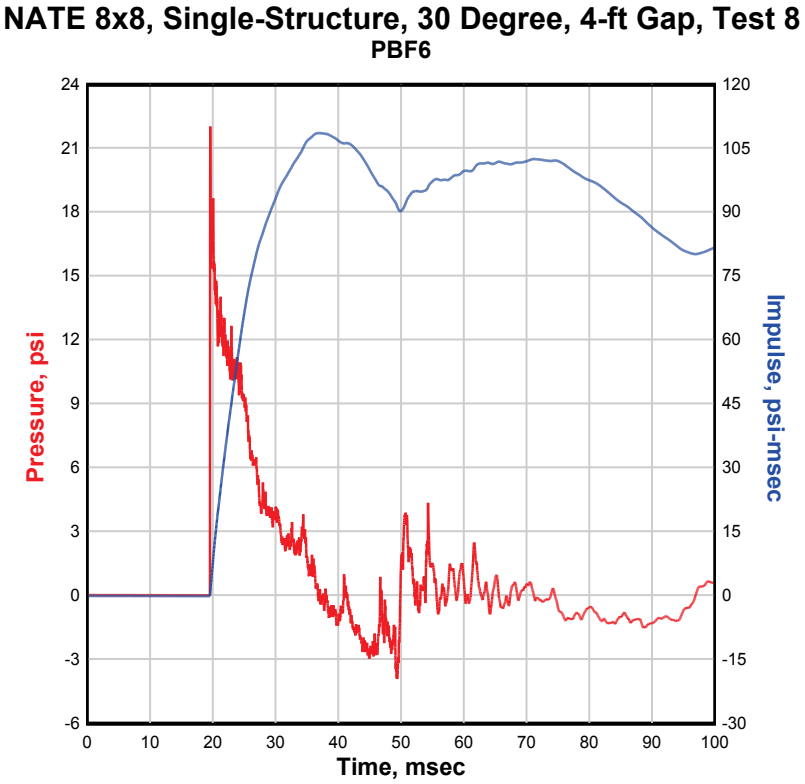
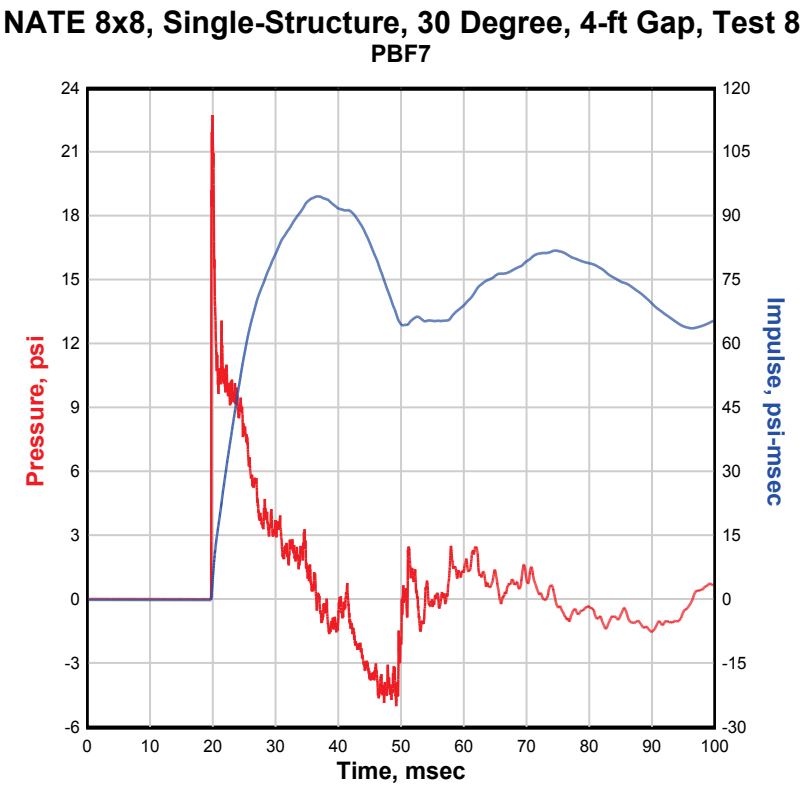
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
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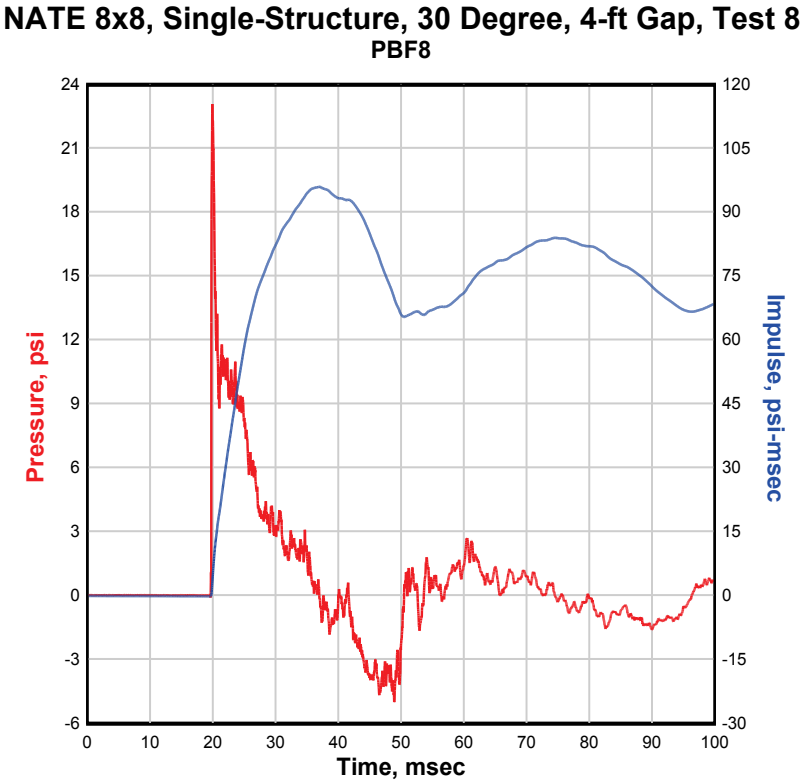
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
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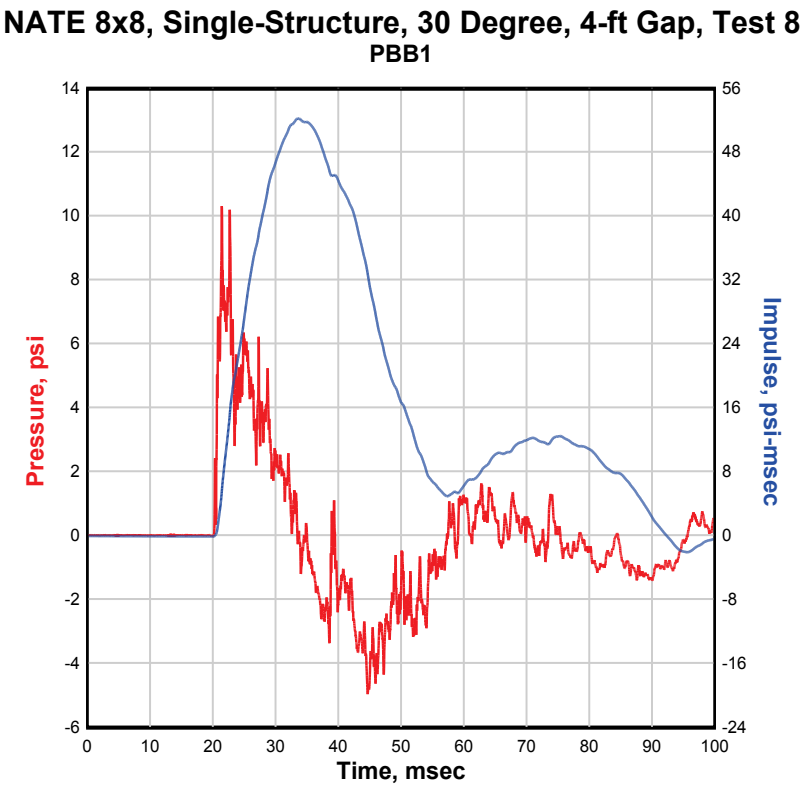
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
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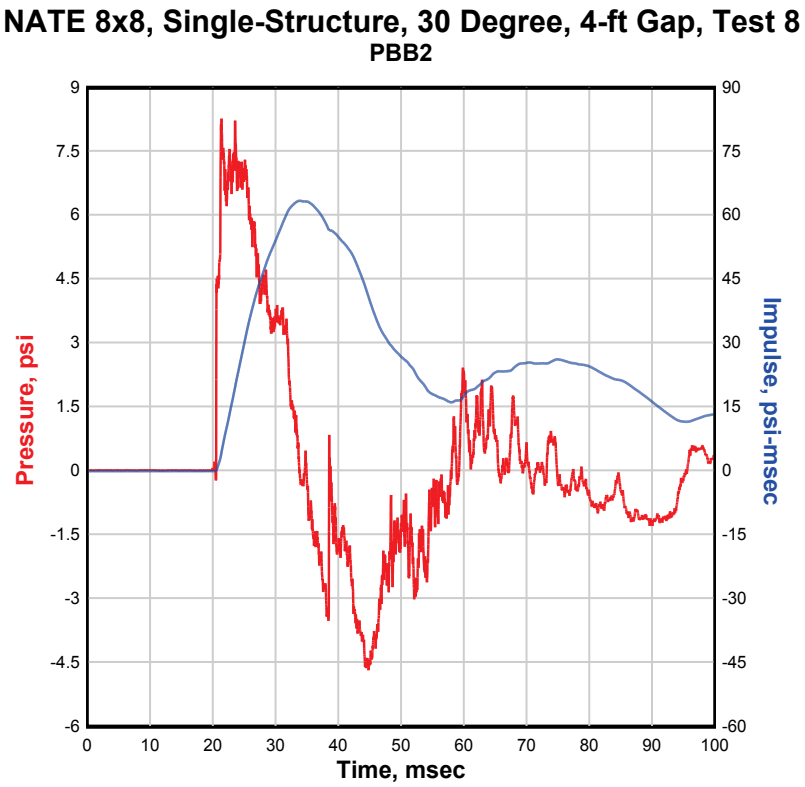
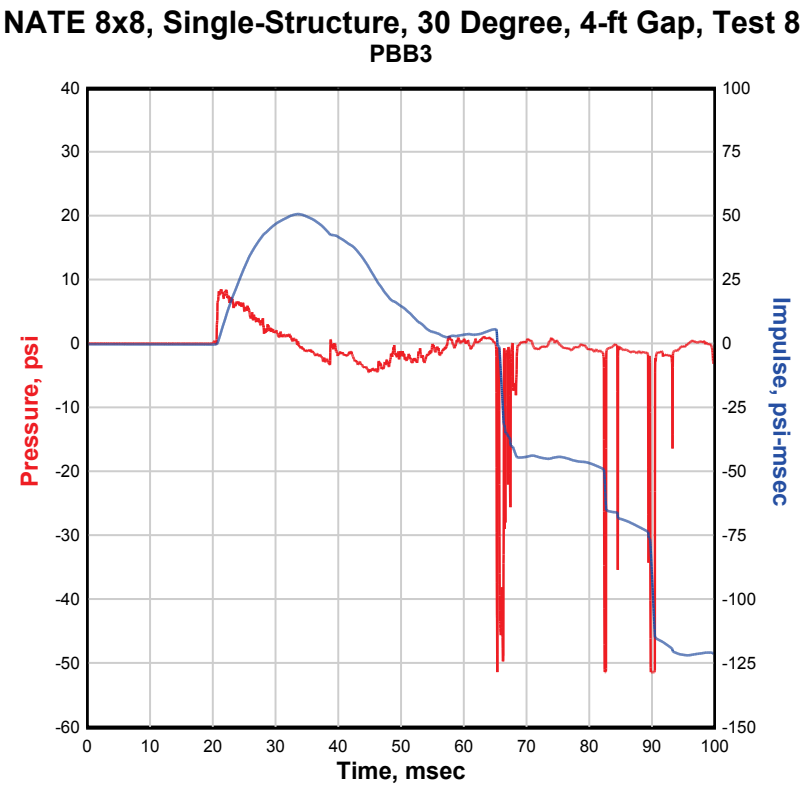
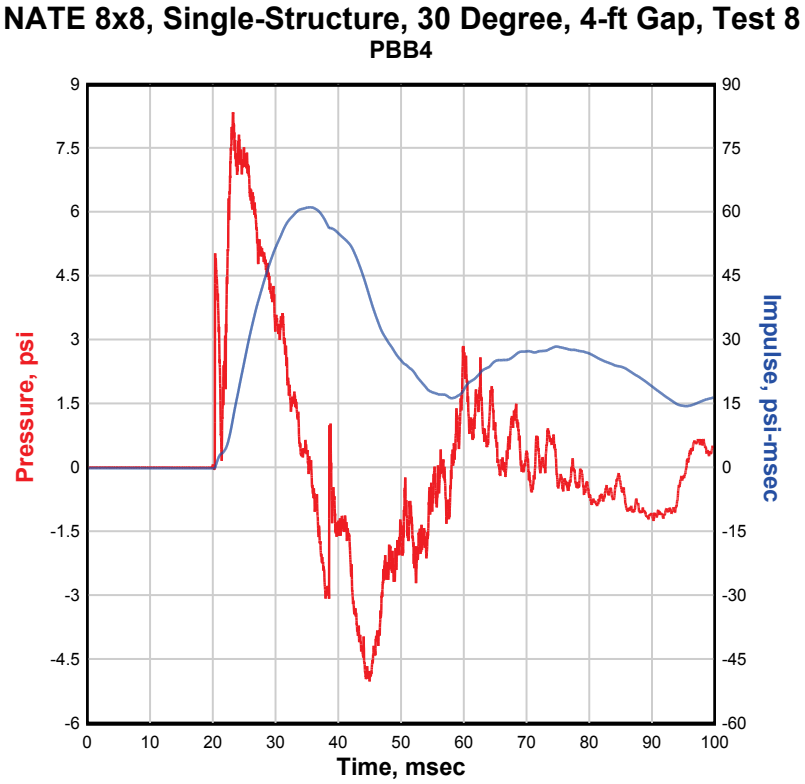
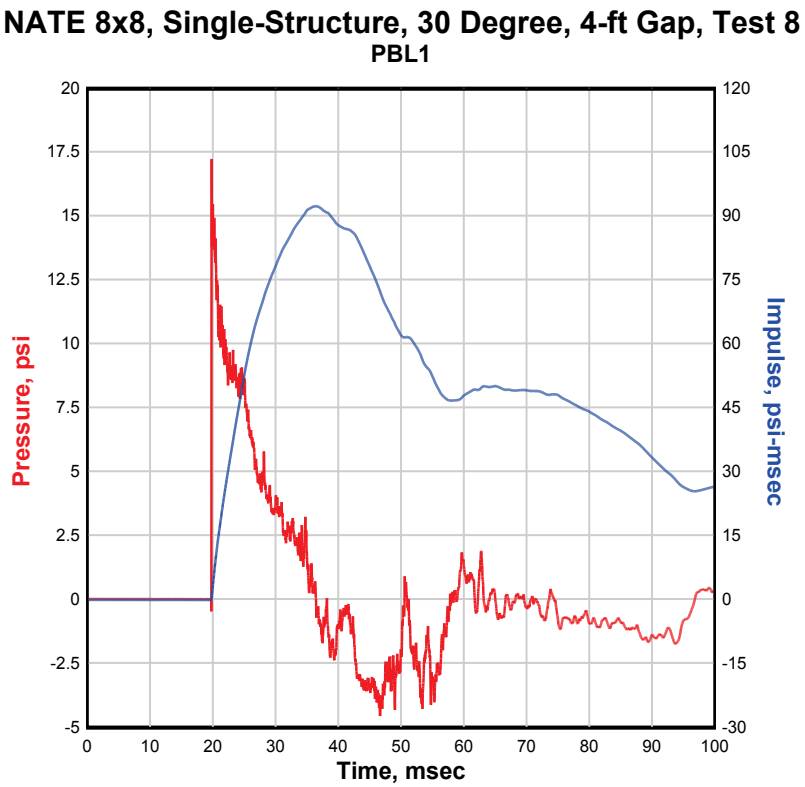
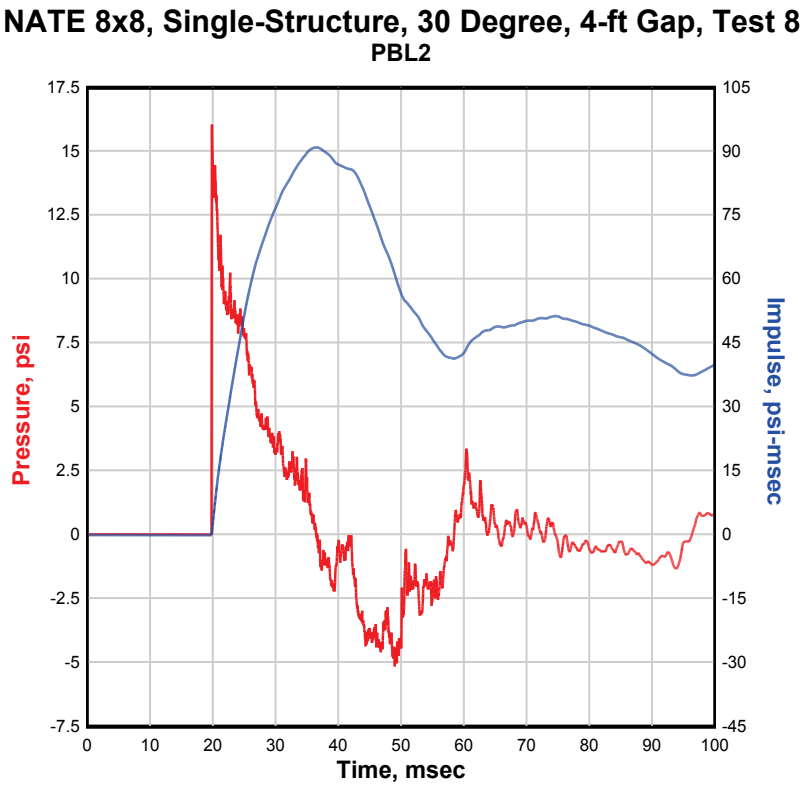
70
80
90
100

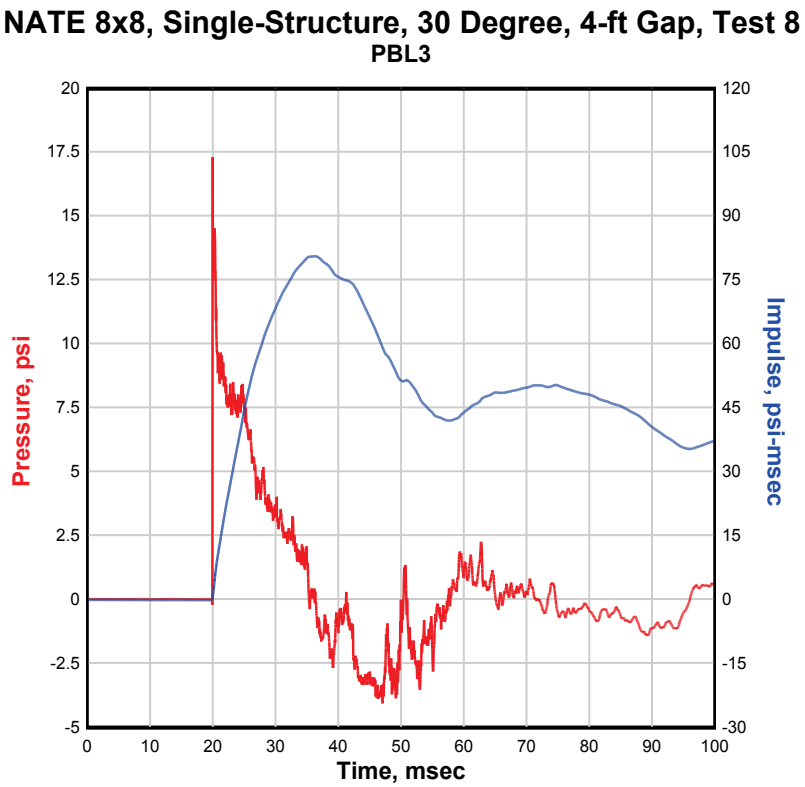

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

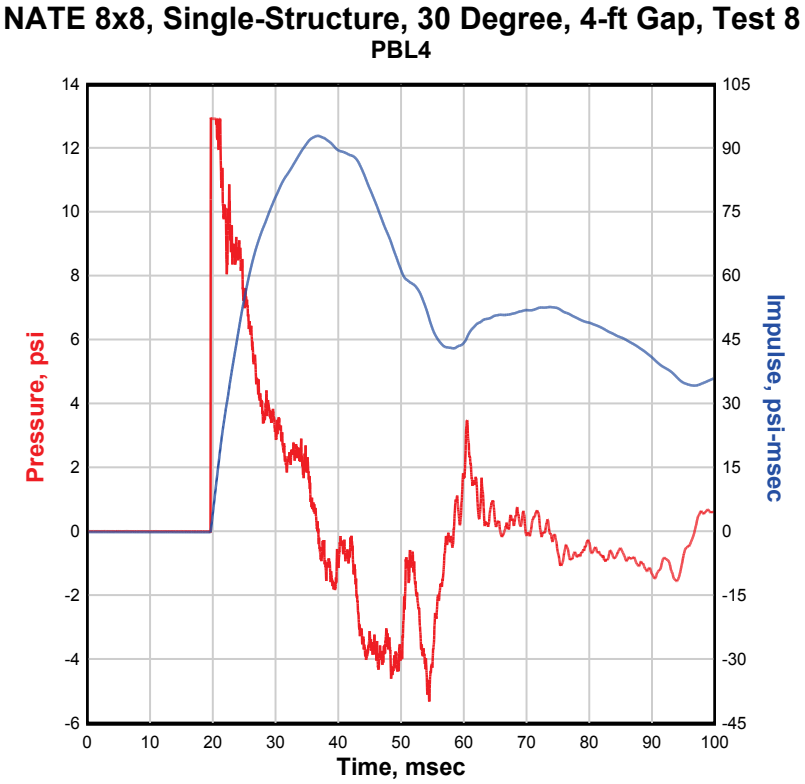

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
40
30
20
10
0
-10
-20
-30
-40
-50
-60
100
75
50
25
0
-25
-50
-75
-100
-125
-150
0
10
20
30
40
50
60
70
80
90
100

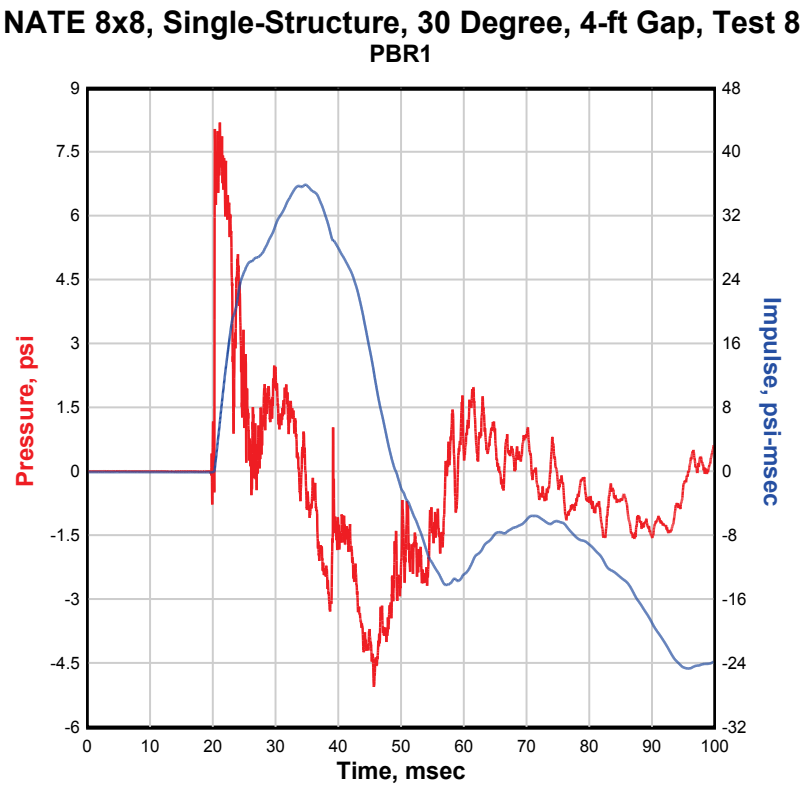

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

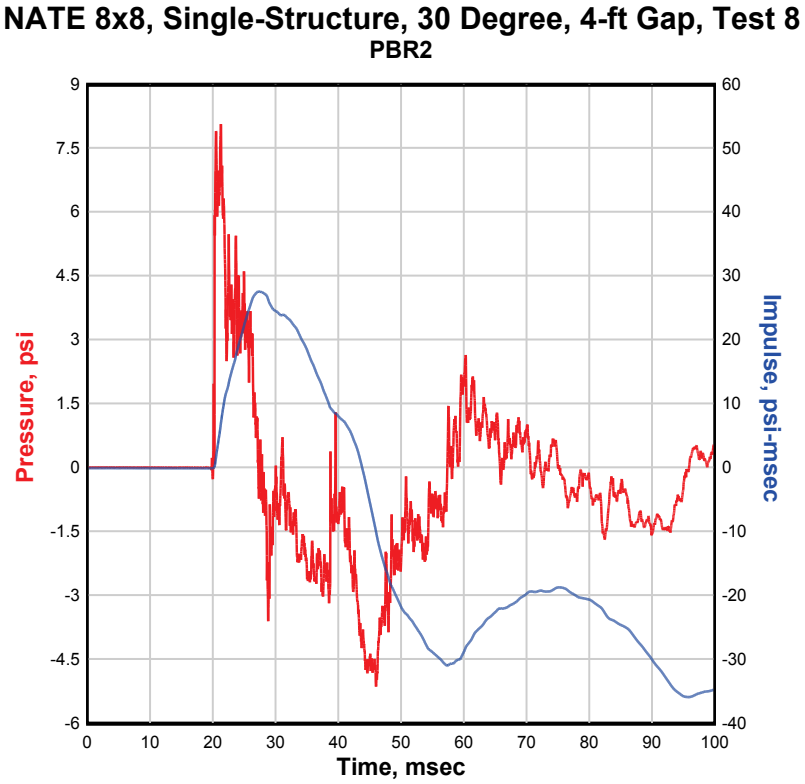

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

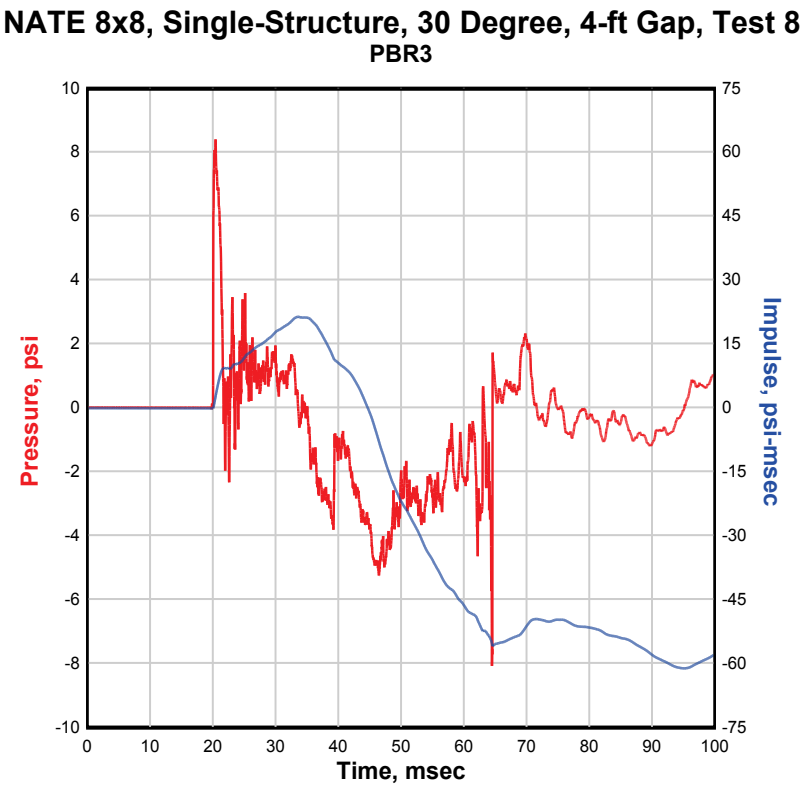

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
-7.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

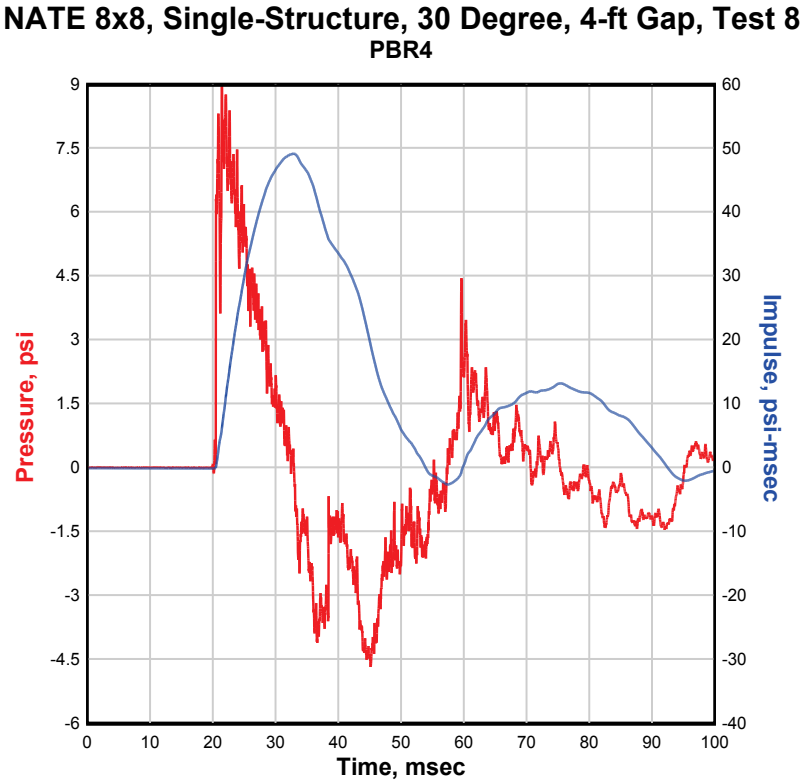

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

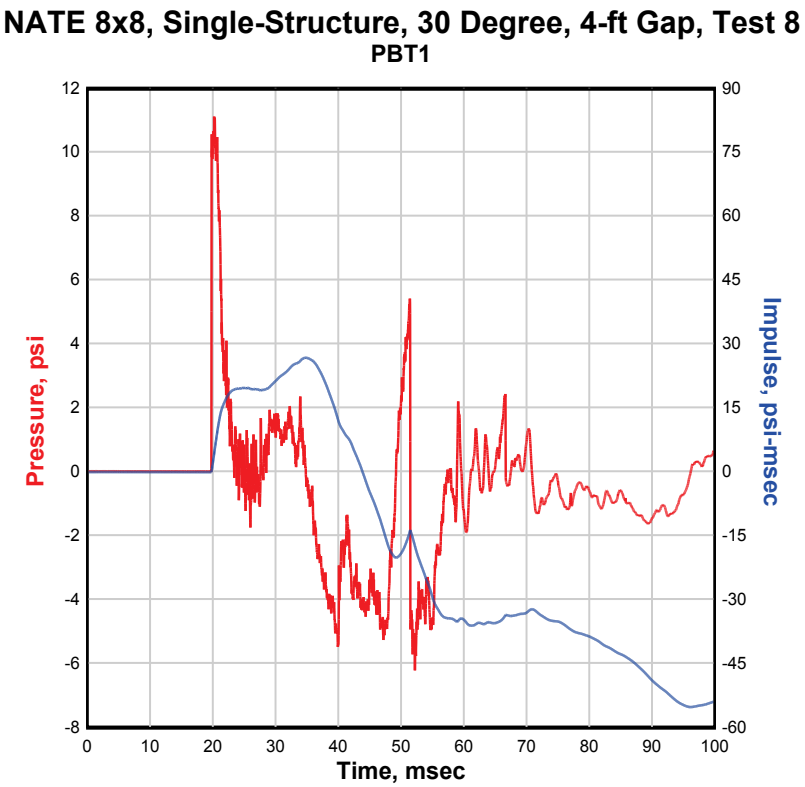

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
10
8
6
4
2
0
-2
-4
-6
-8
-10
75
60
45
30
15
0
-15
-30
-45
-60
-75
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
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60
70
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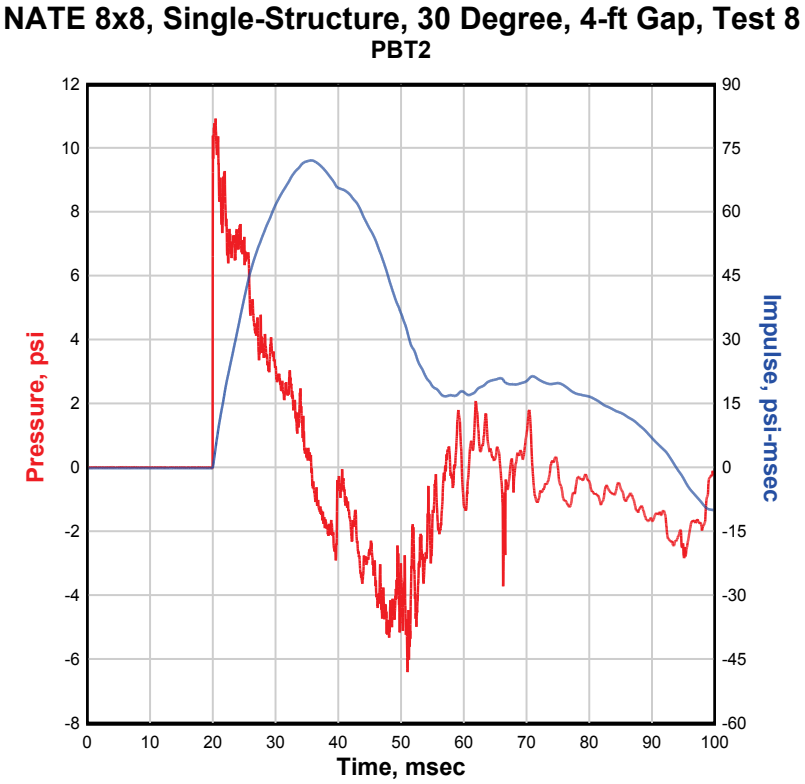
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
90
75
60
45
30
15
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-15
-30
-45
-60
0
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30
40
50
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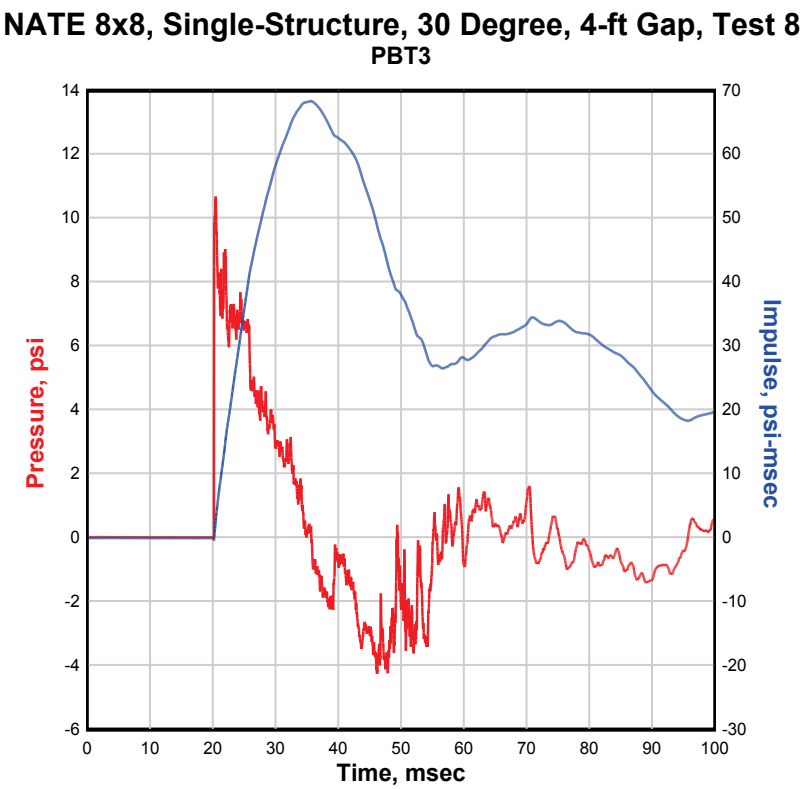
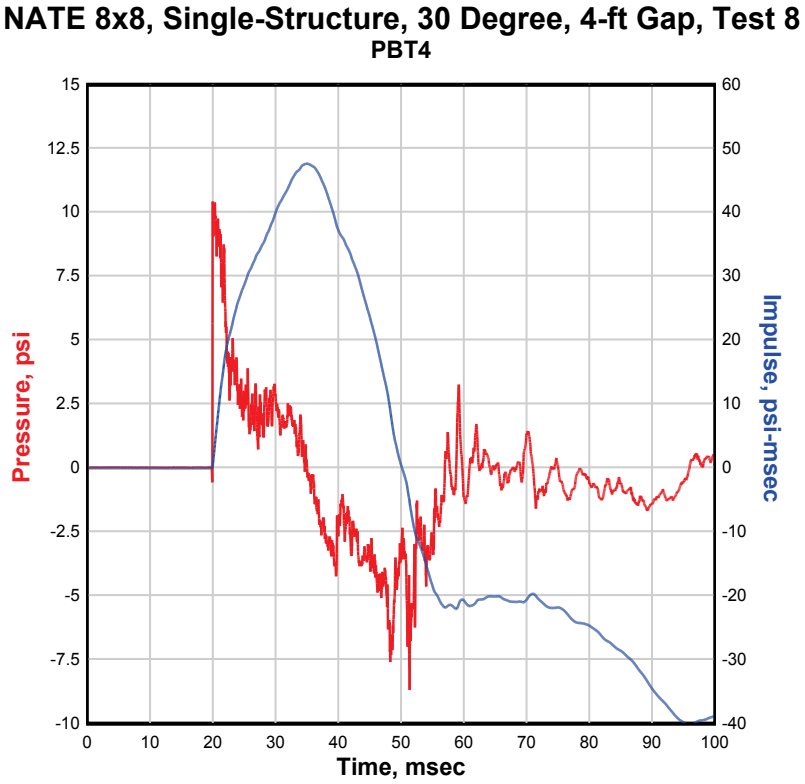
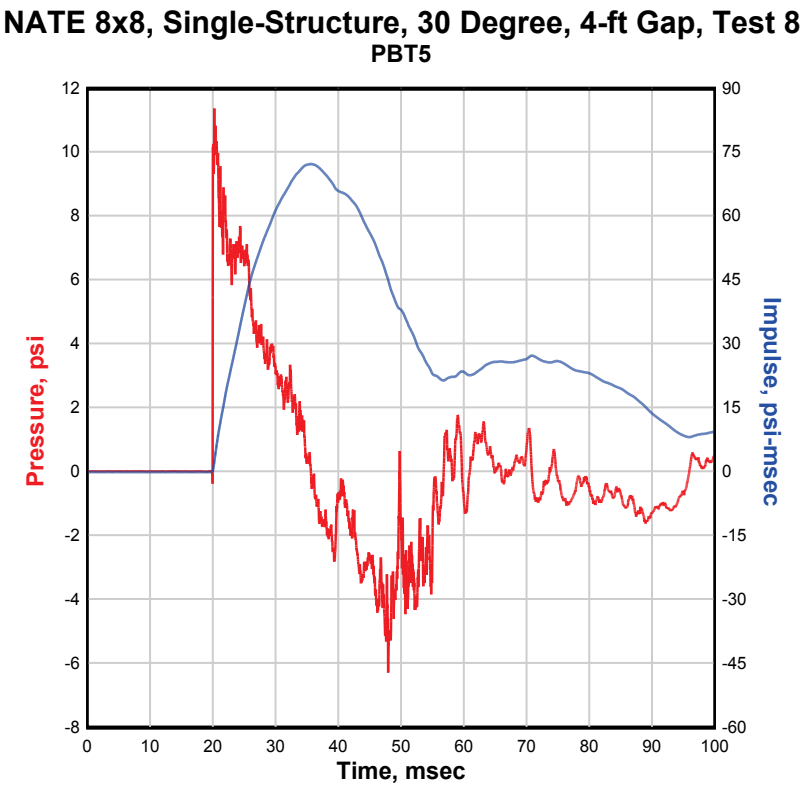
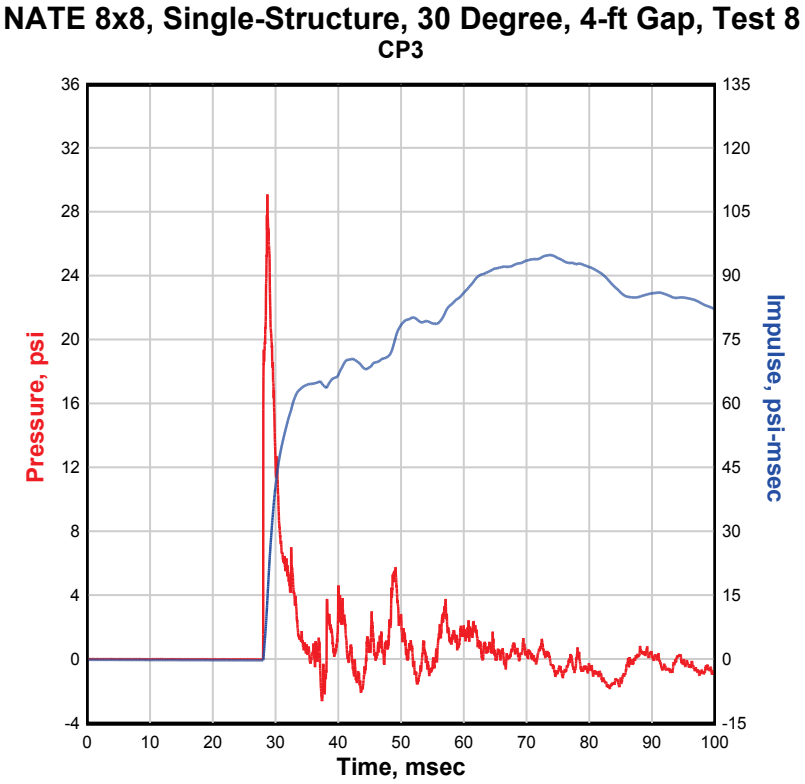
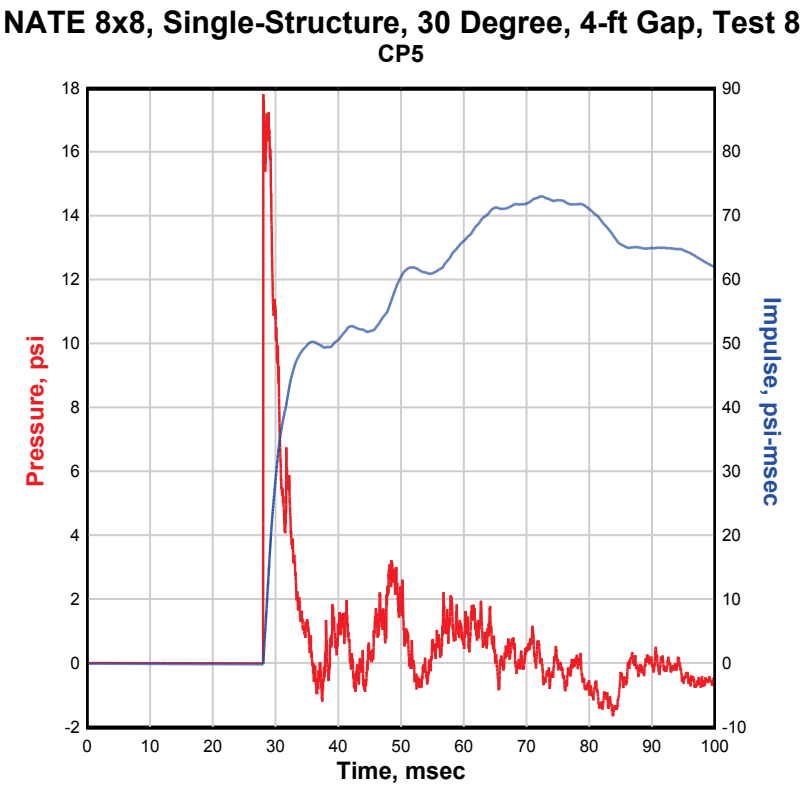
70
80
90
100

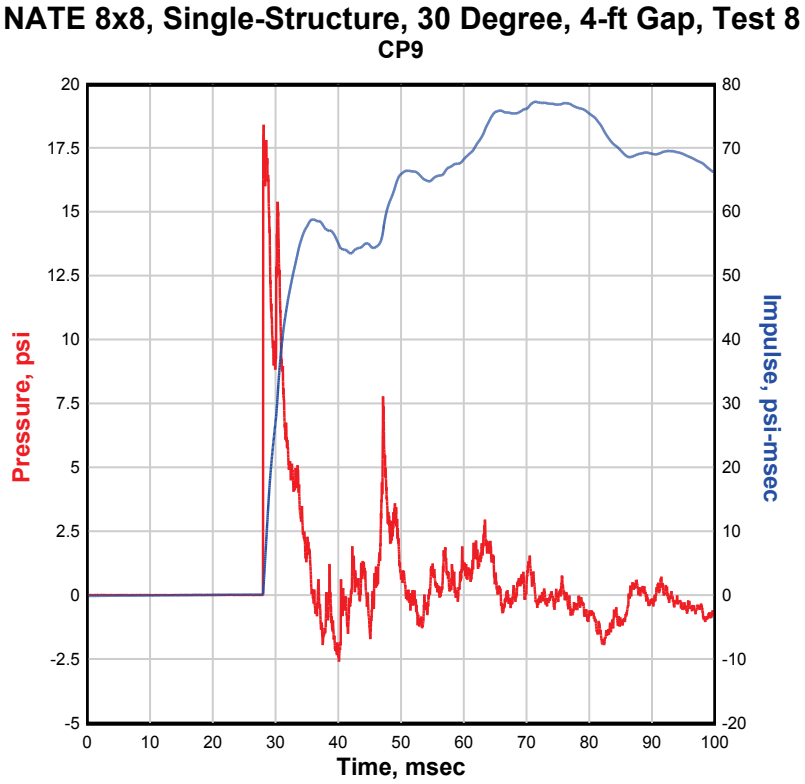

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

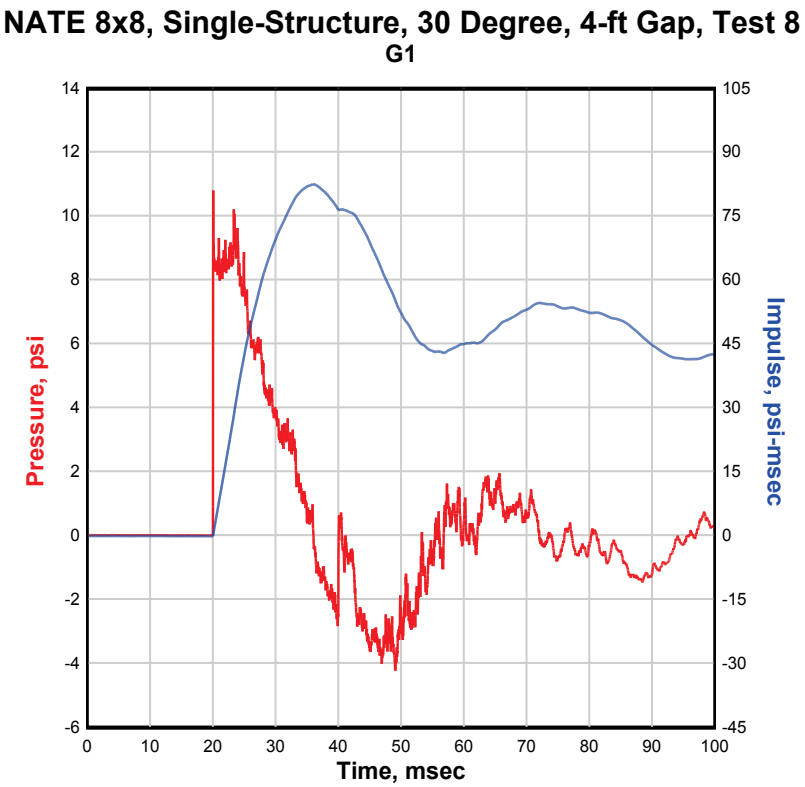

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
15
12.5
10
7.5
5
2.5
0
-2.5
-5
-7.5
-10
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100

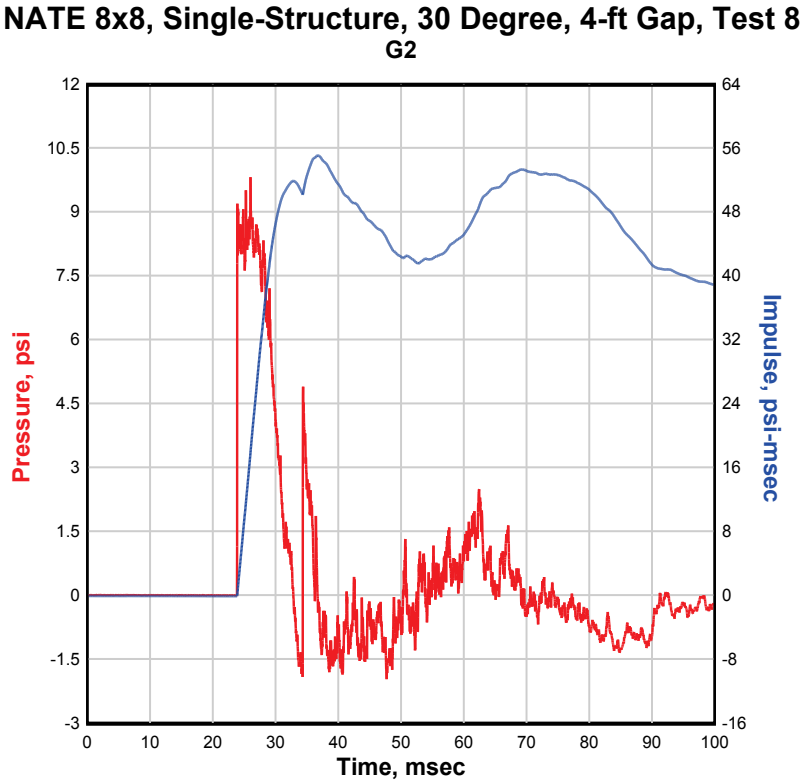

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

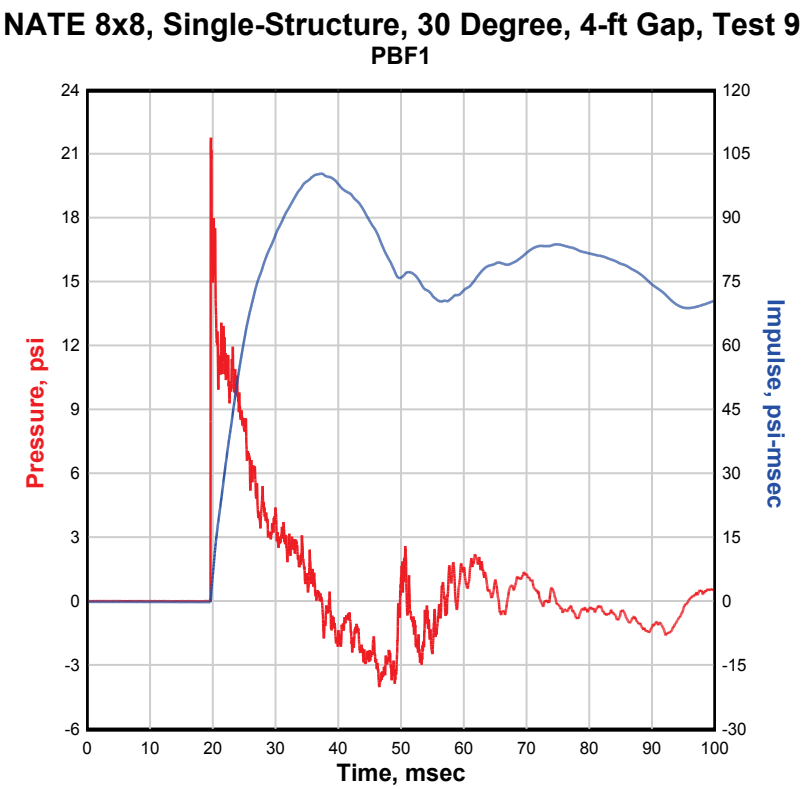

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
18
16
14
12
10
8
6
4
2
0
-2
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
80
70
60
50
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
G1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 8
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
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-30
0
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30
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70
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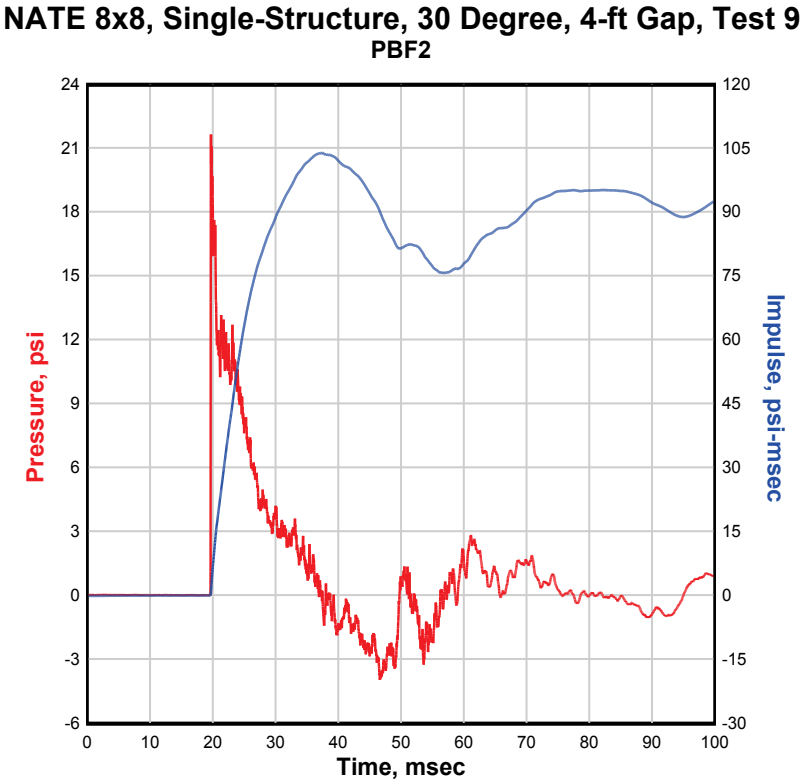
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
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-30
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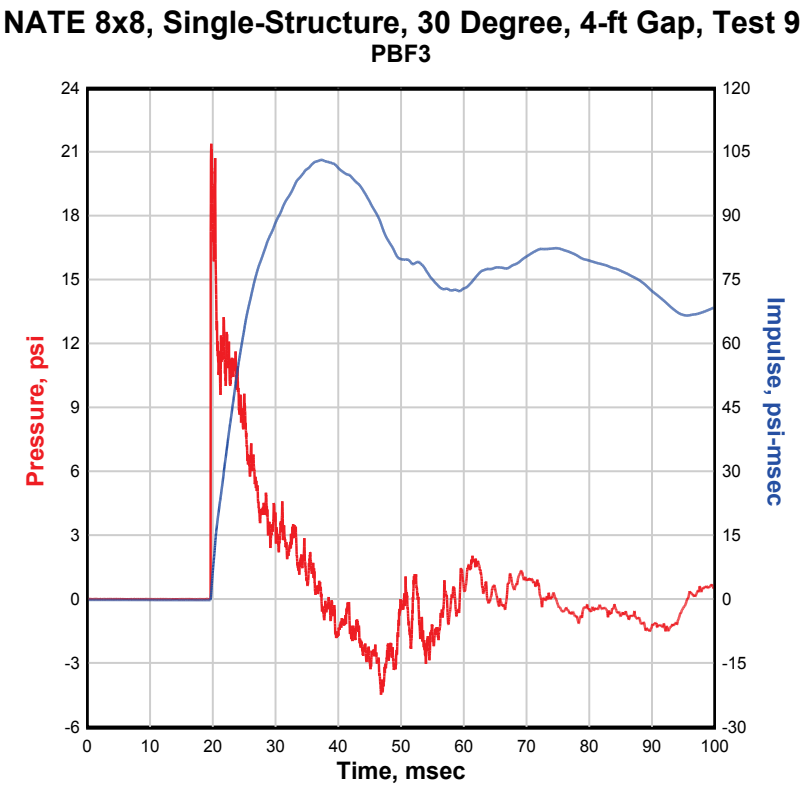
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
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30
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0
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-30
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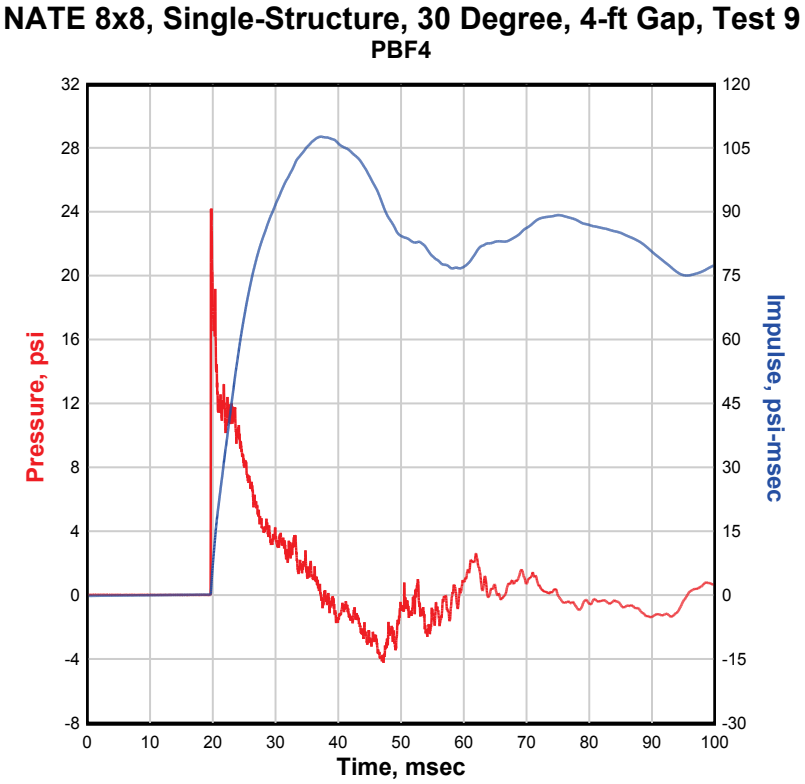
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
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60
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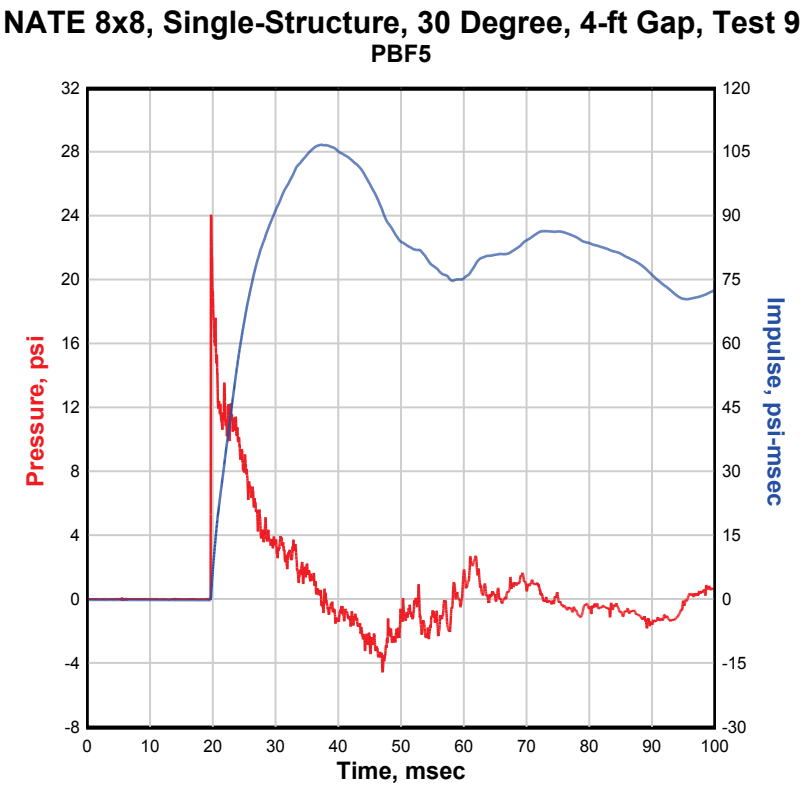
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
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-30
0
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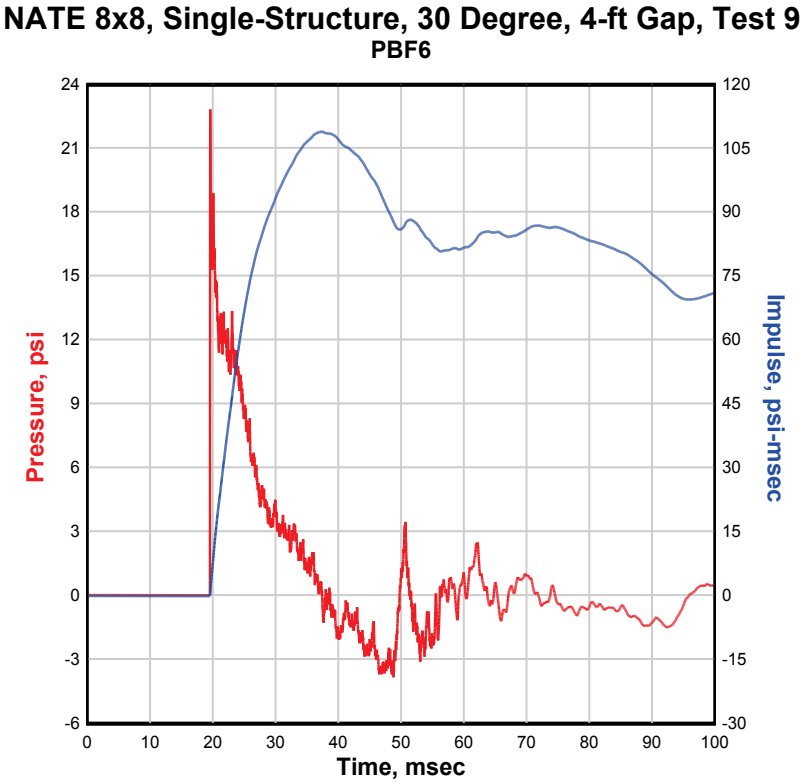
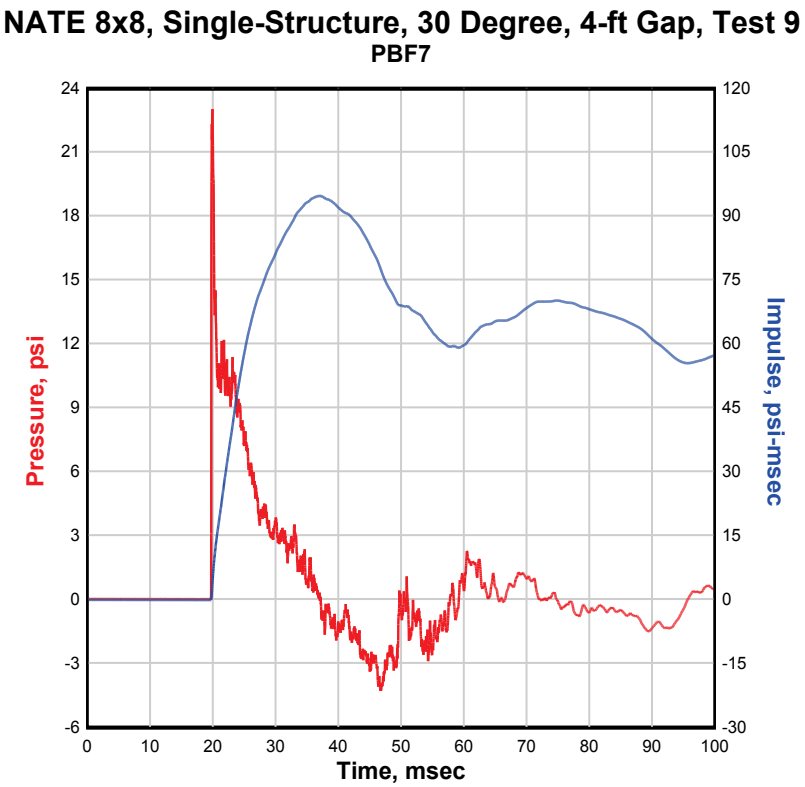
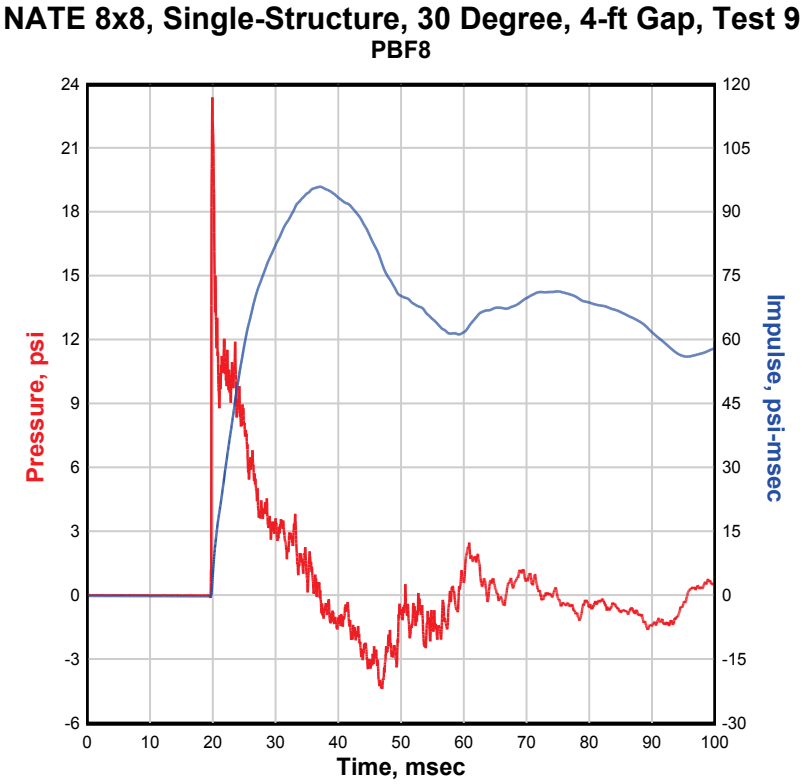
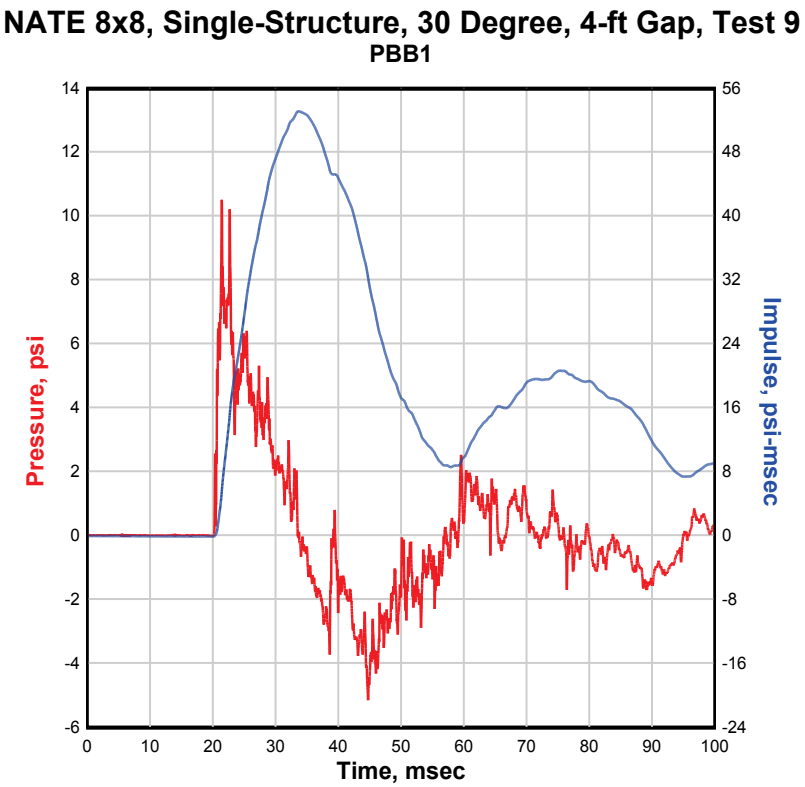
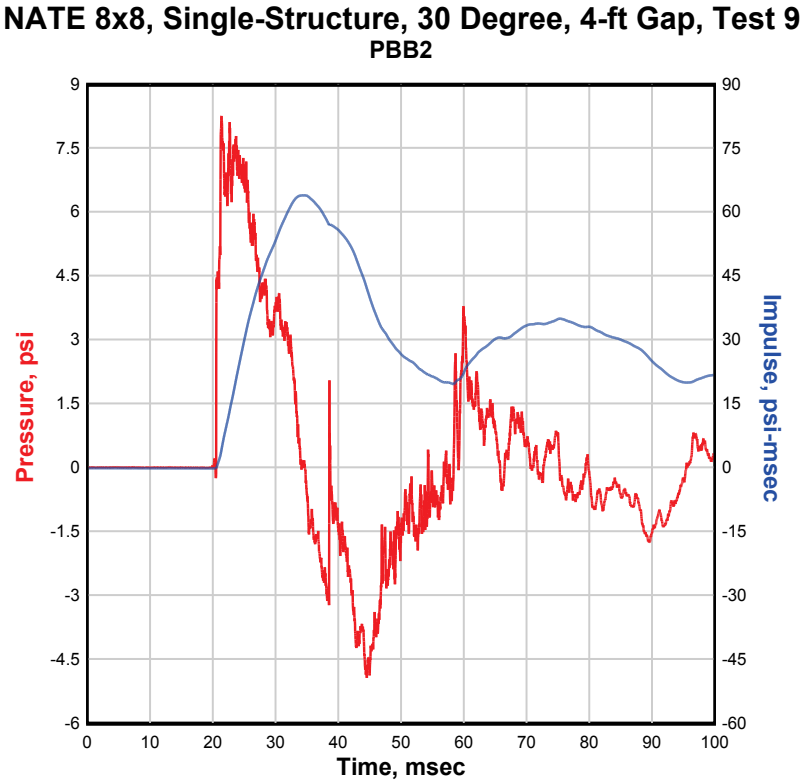
100

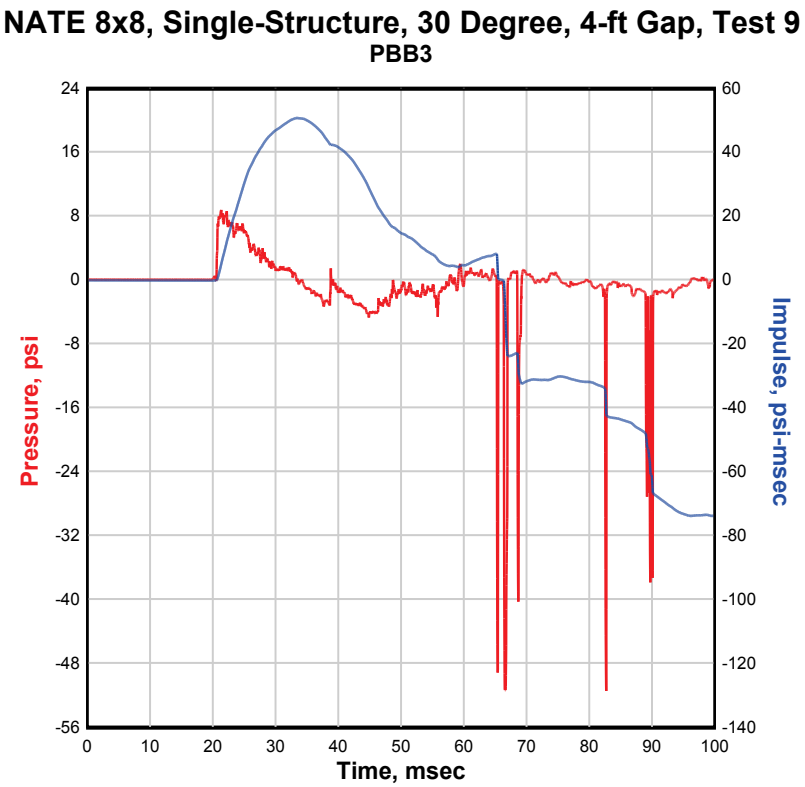

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
0
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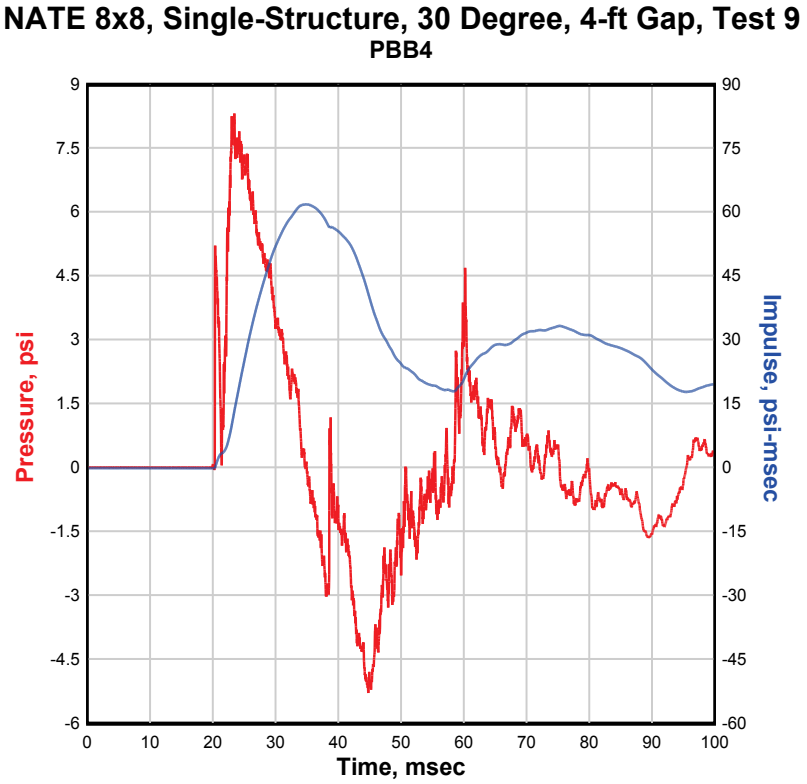
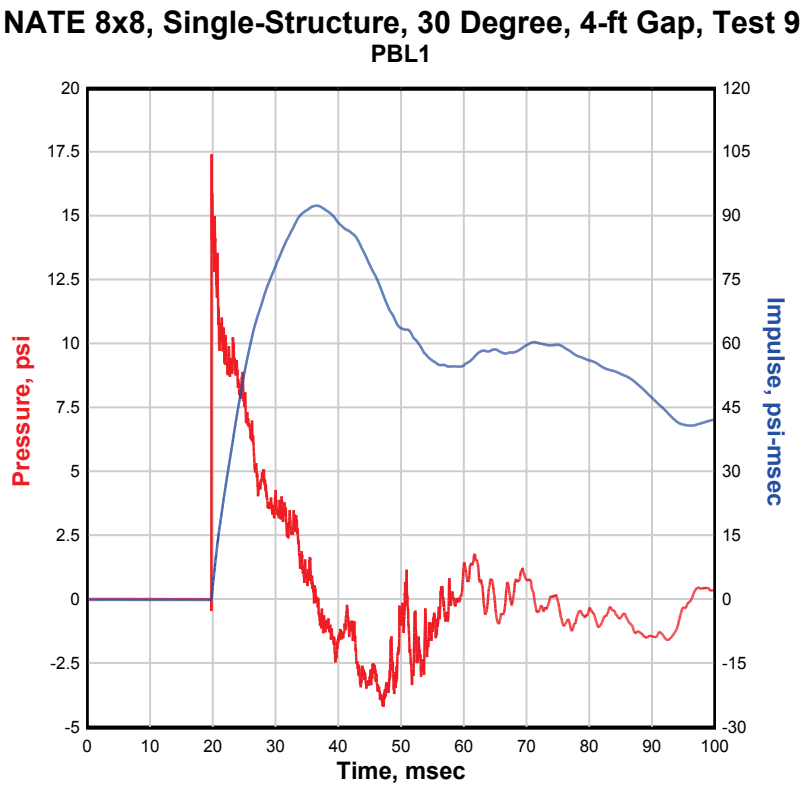
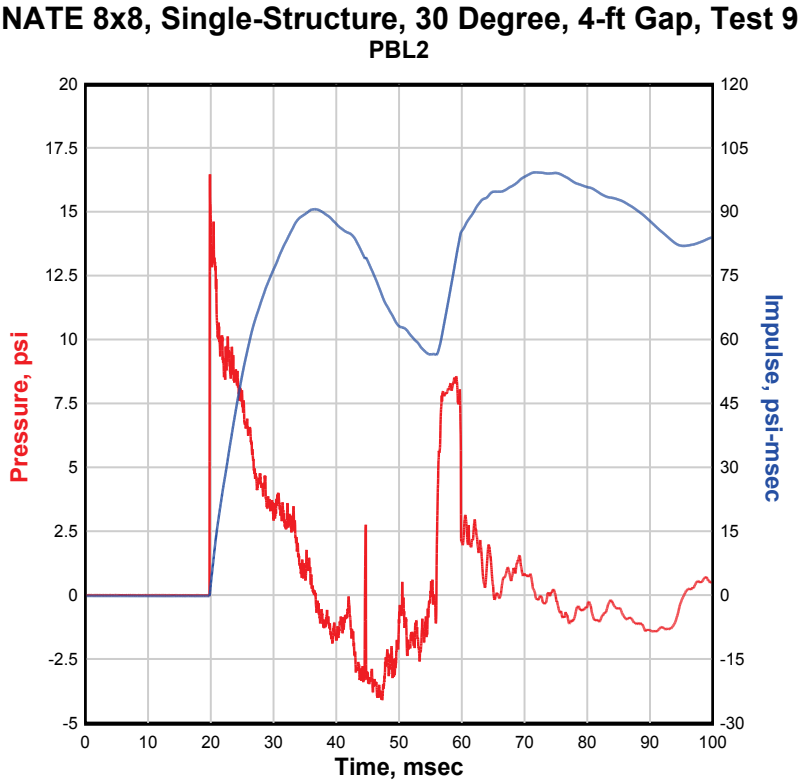
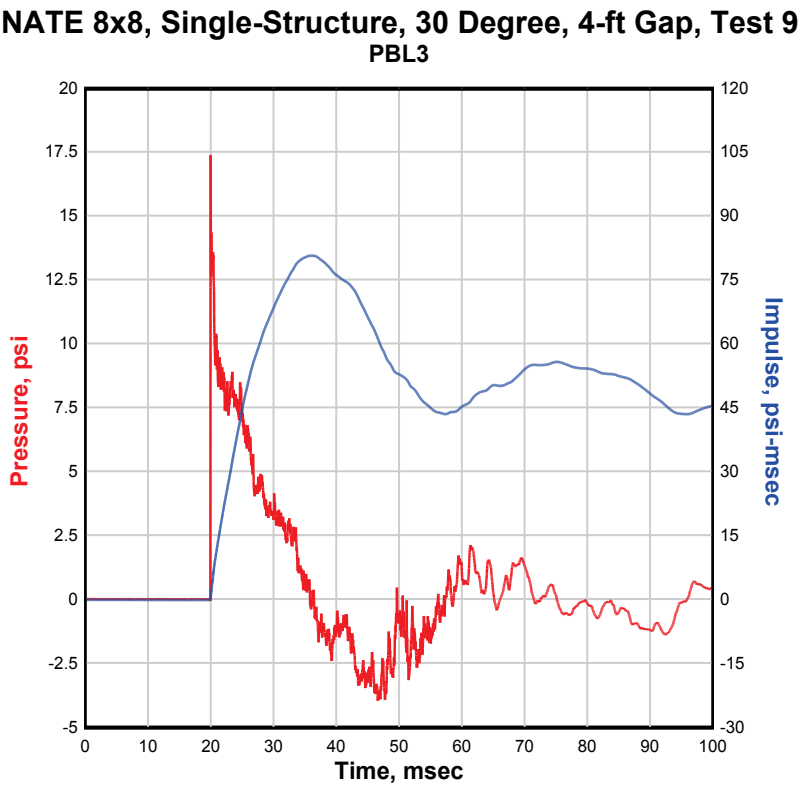
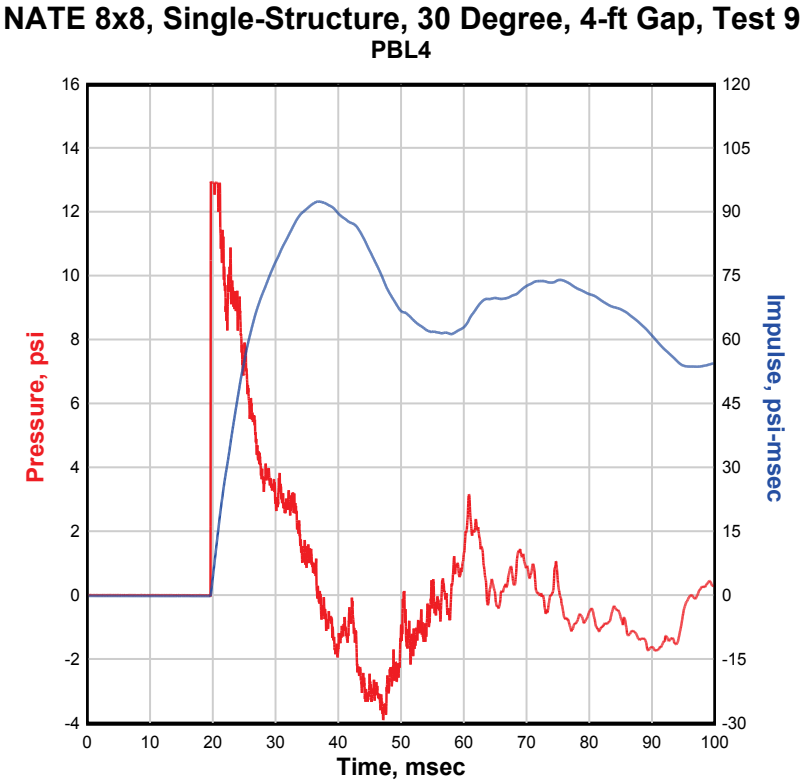
20
30
40
50
60
70
80
90
100

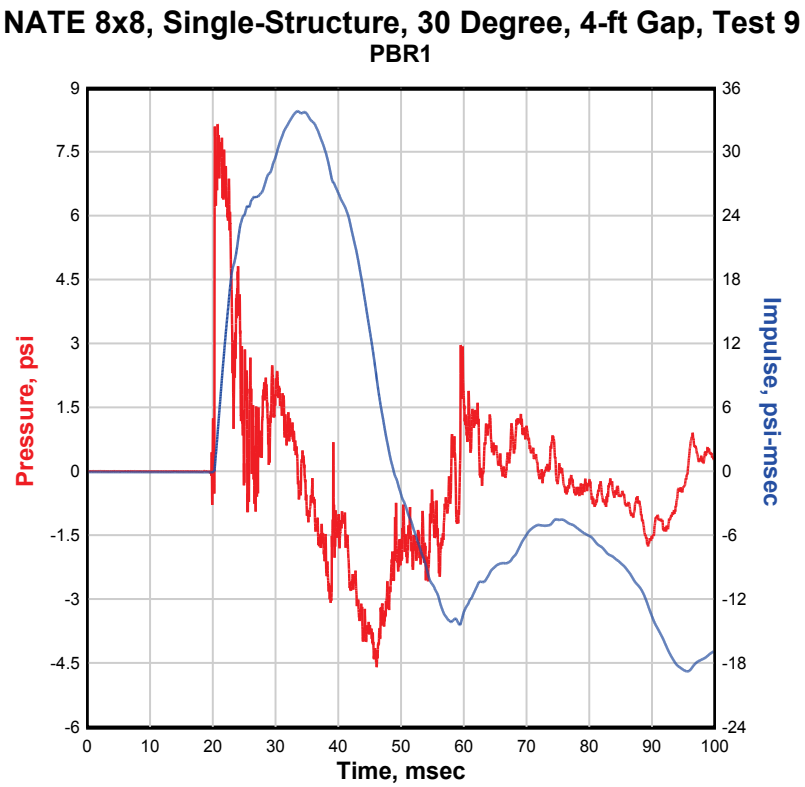

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

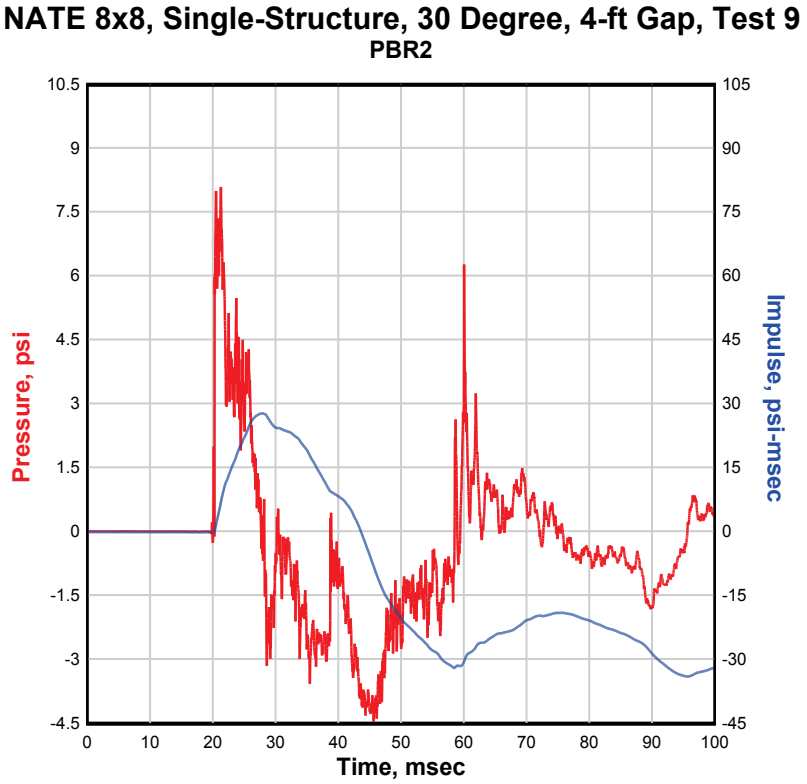

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
36
30
24
18
12
6
0
-6
-12
-18
-24
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
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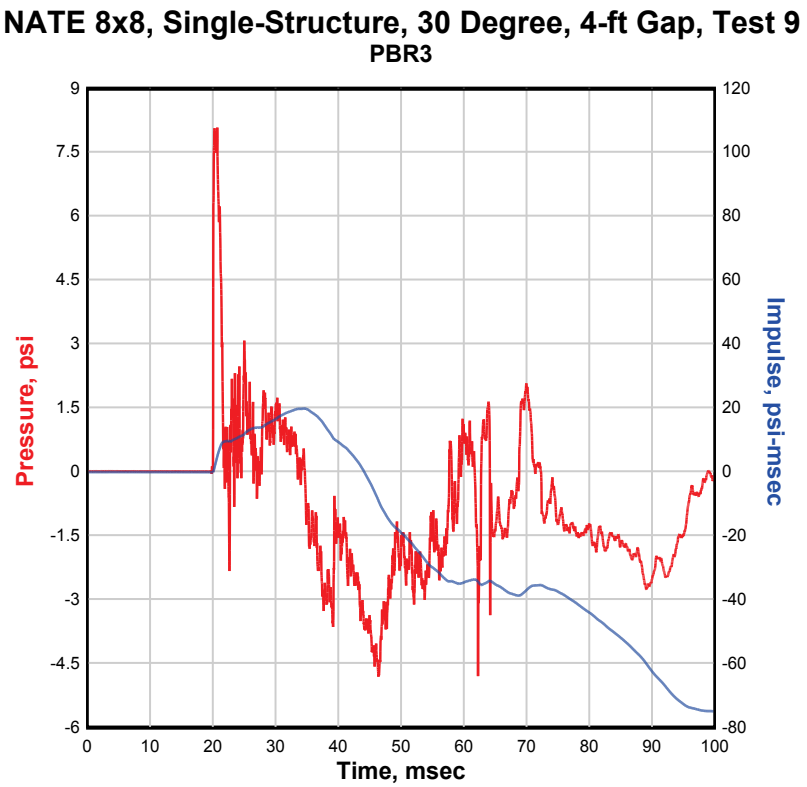
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
120
100
80
60
40
20
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-20
-40
-60
-80
0
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30
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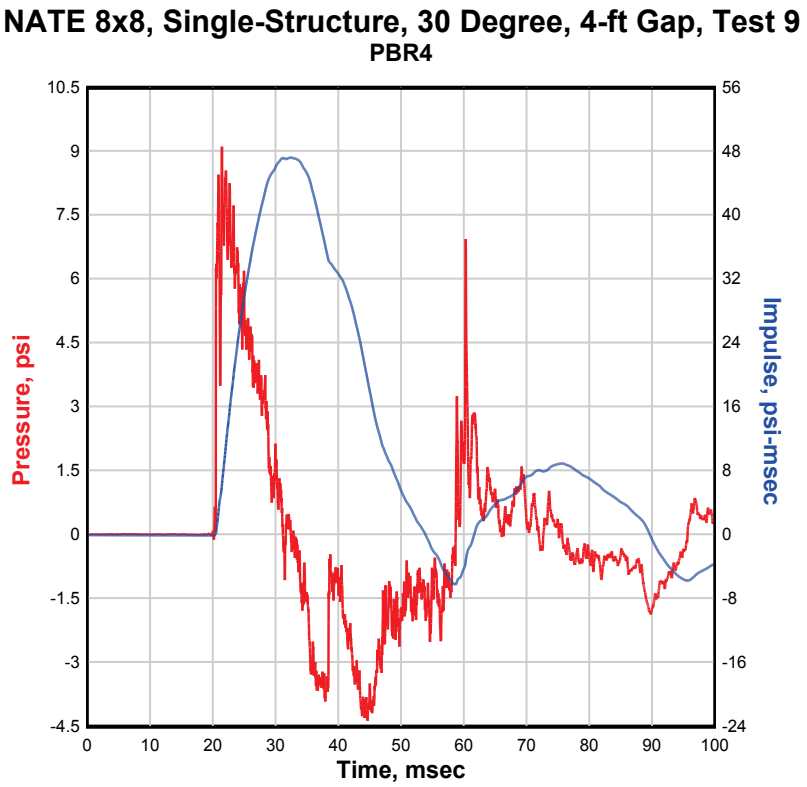
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
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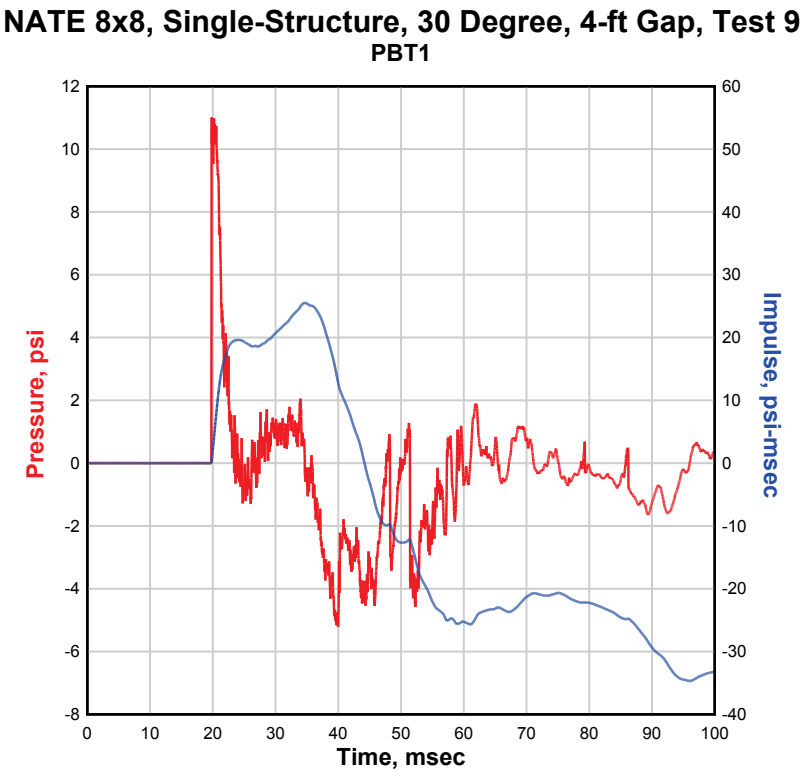
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
60
50
40
30
20
10
0
-10
-20
-30
-40
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10
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30
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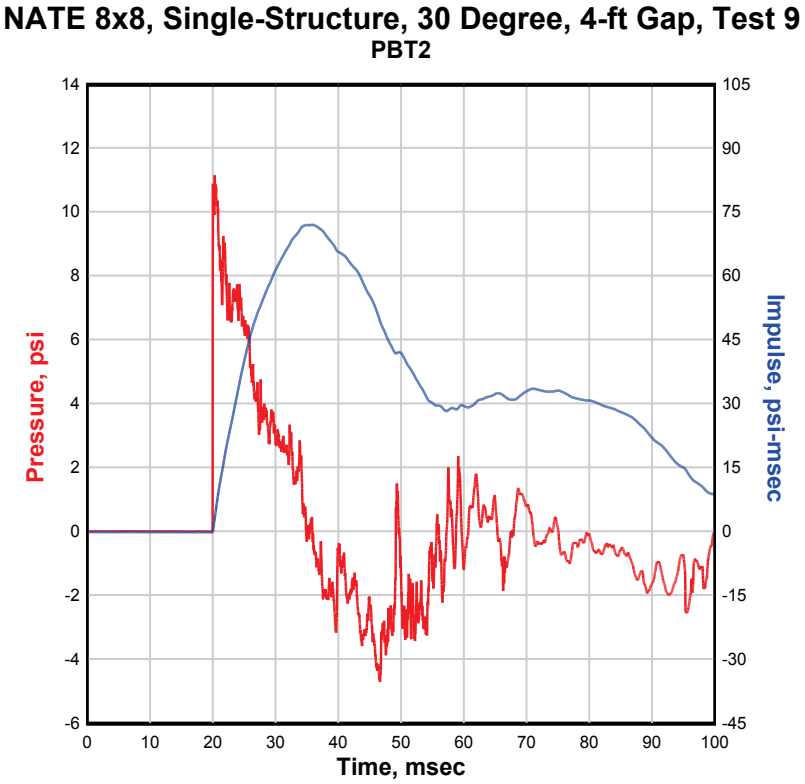
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
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0
-15
-30
-45
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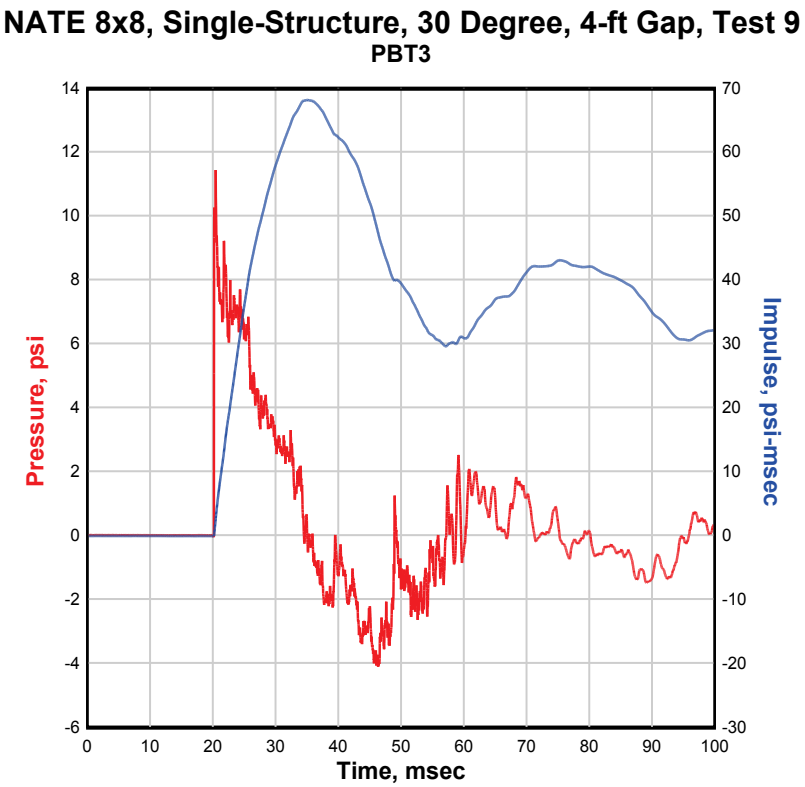
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
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20
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0
-10
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-30
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30
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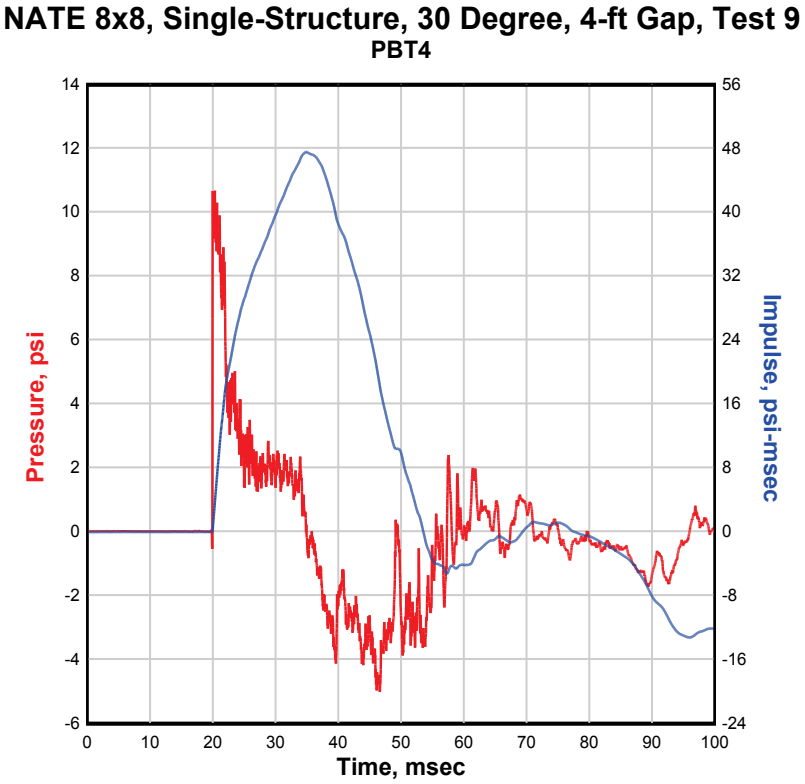
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
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90
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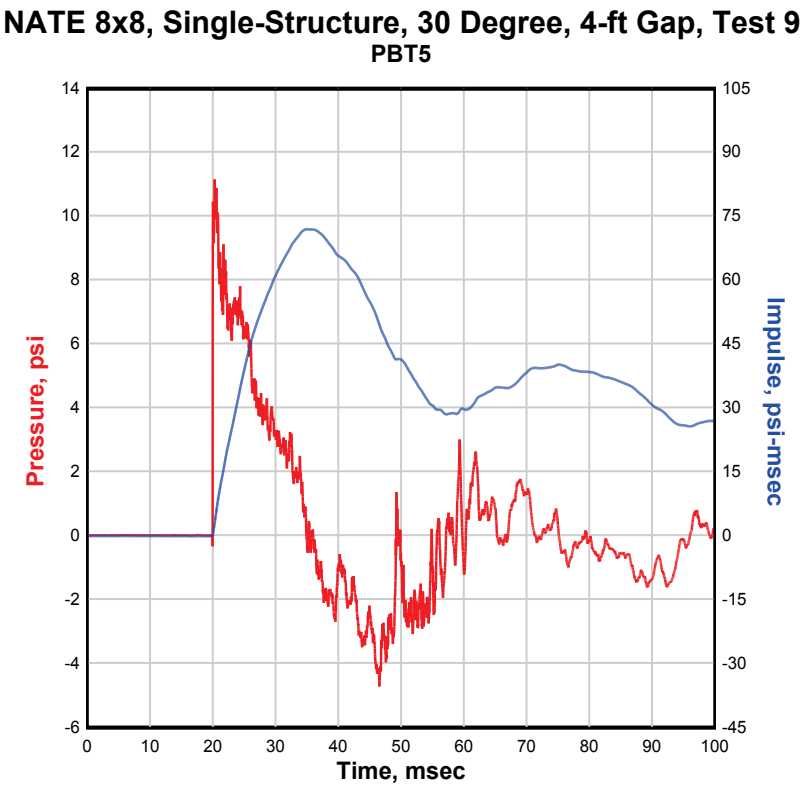
NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
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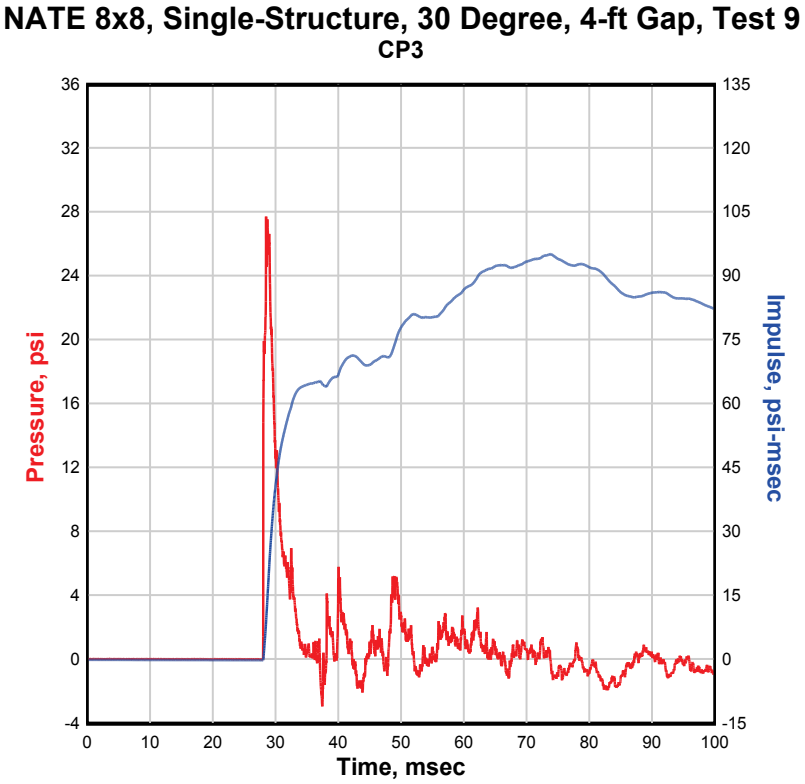
NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
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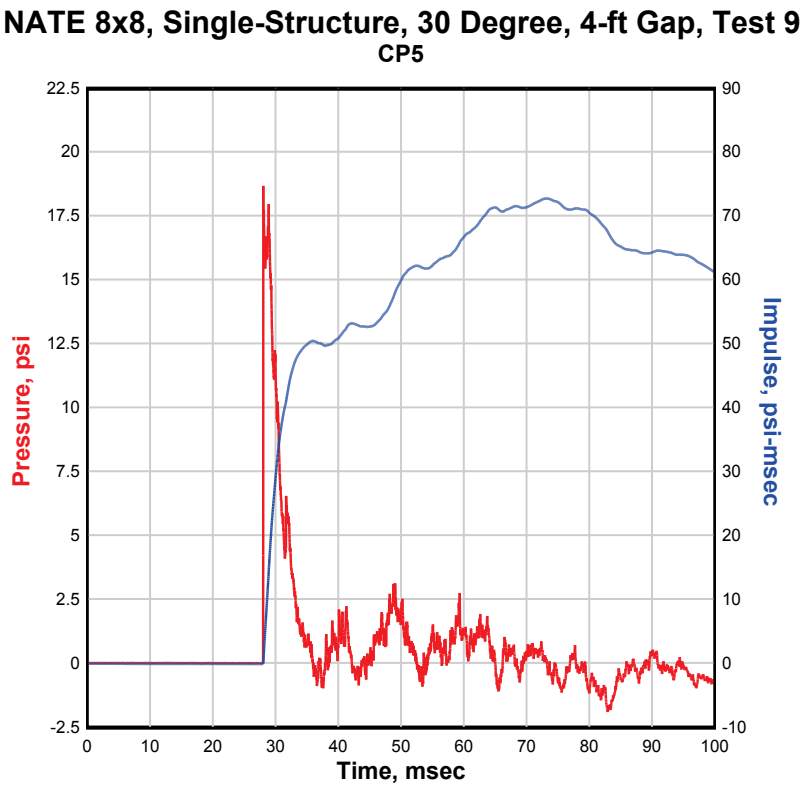
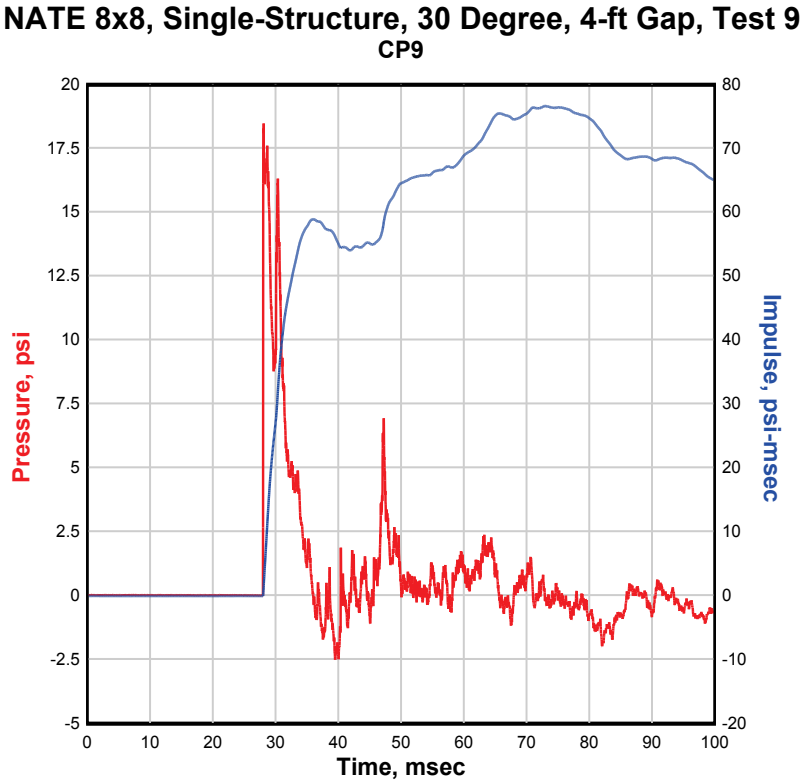
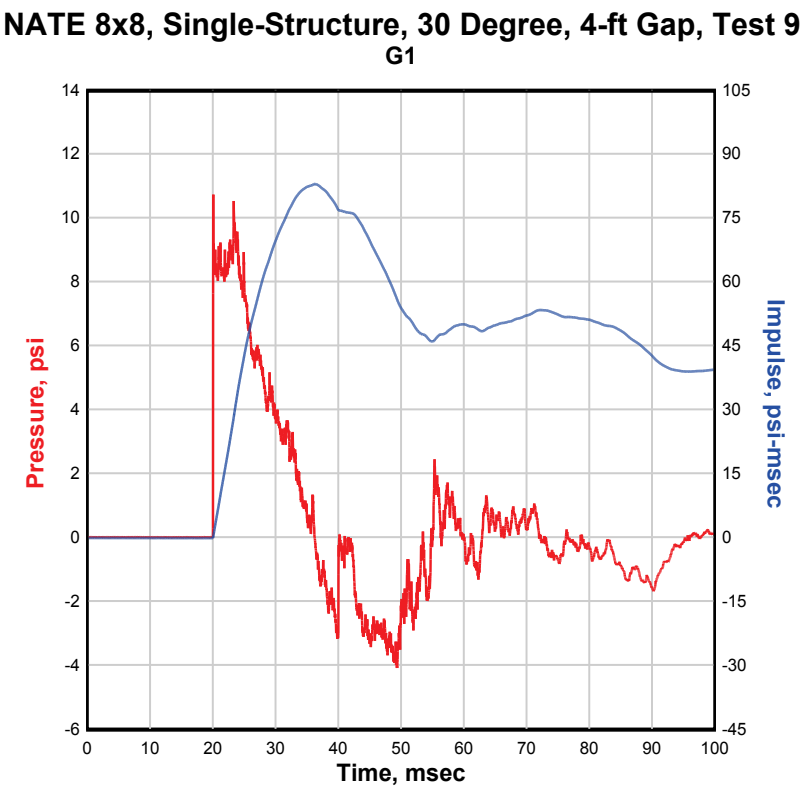
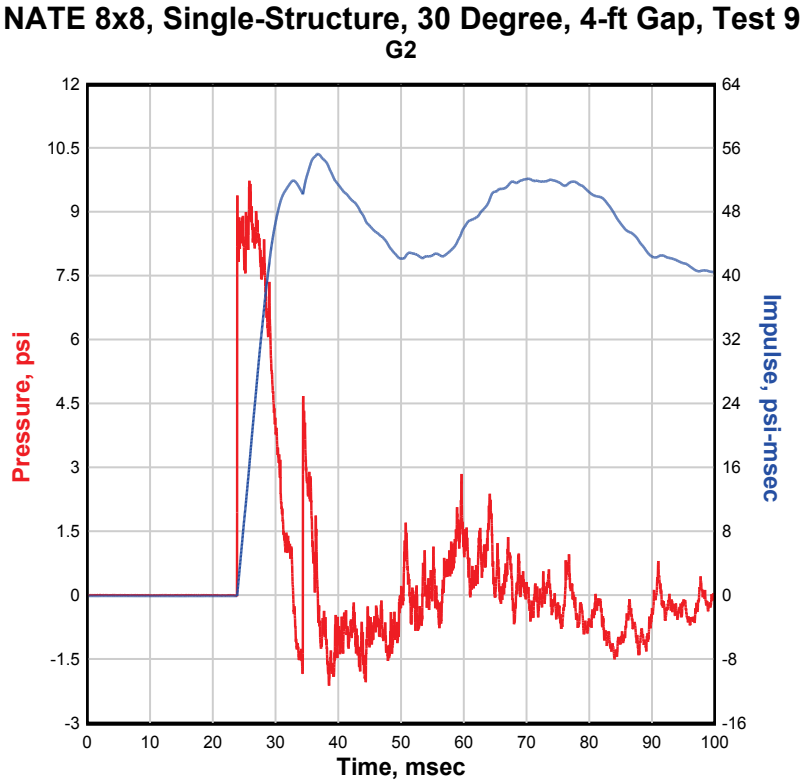
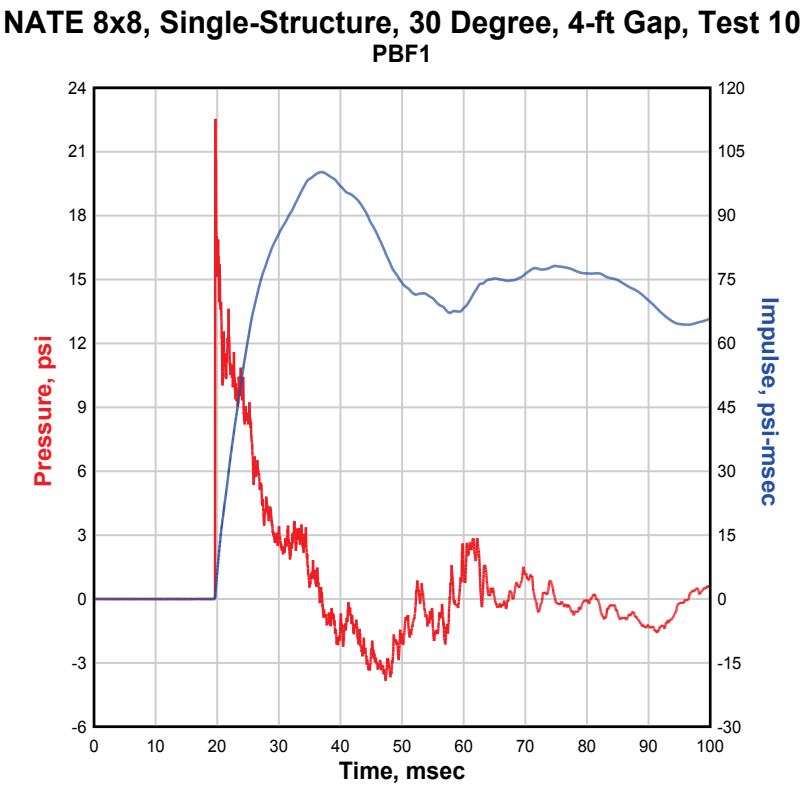
30
40
50
60
70
80
90
100

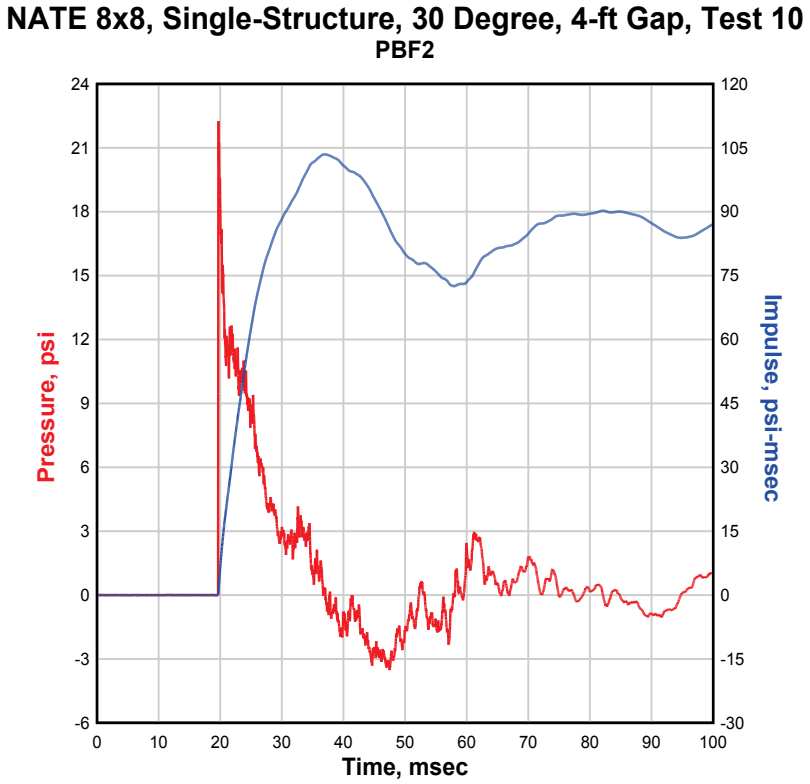

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

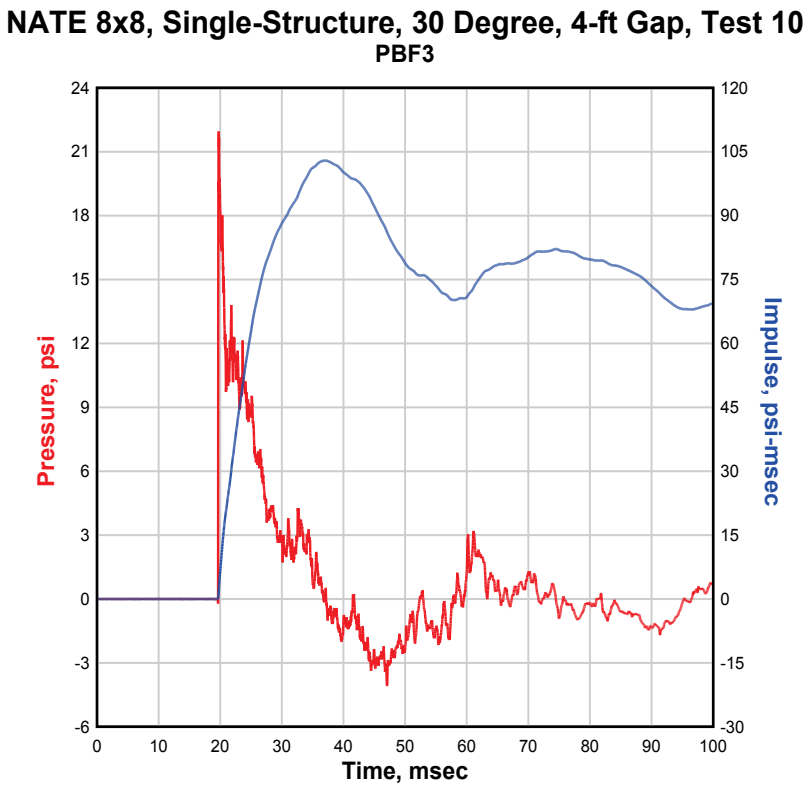

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
80
70
60
50
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100

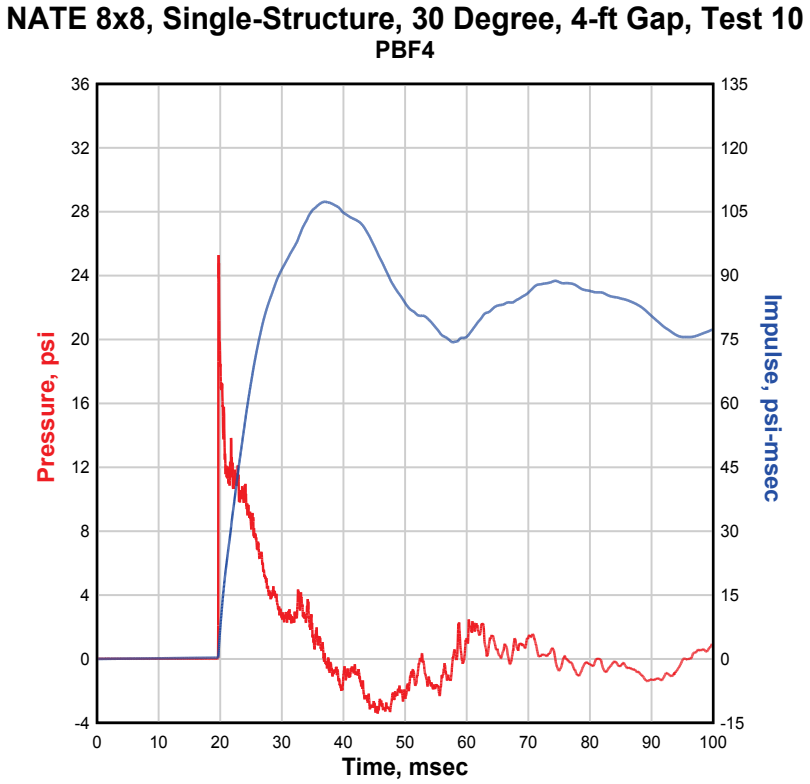

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
G1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

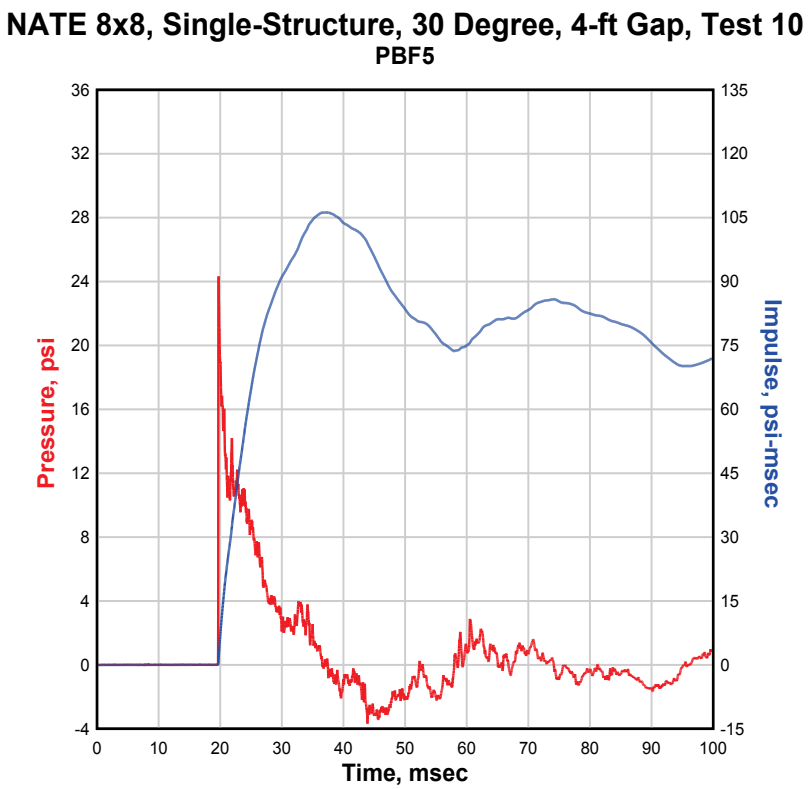

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 9
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

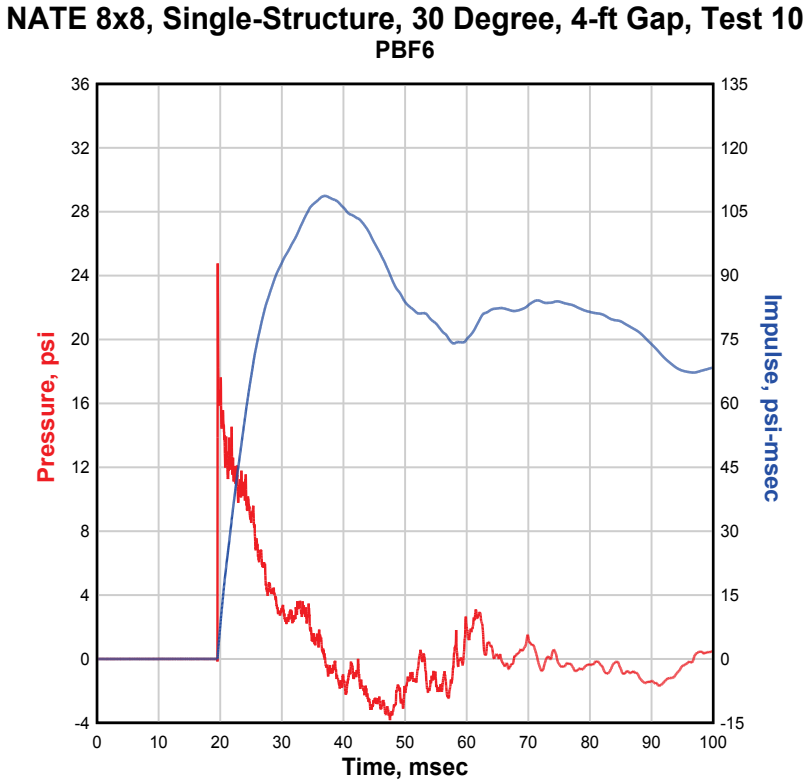

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

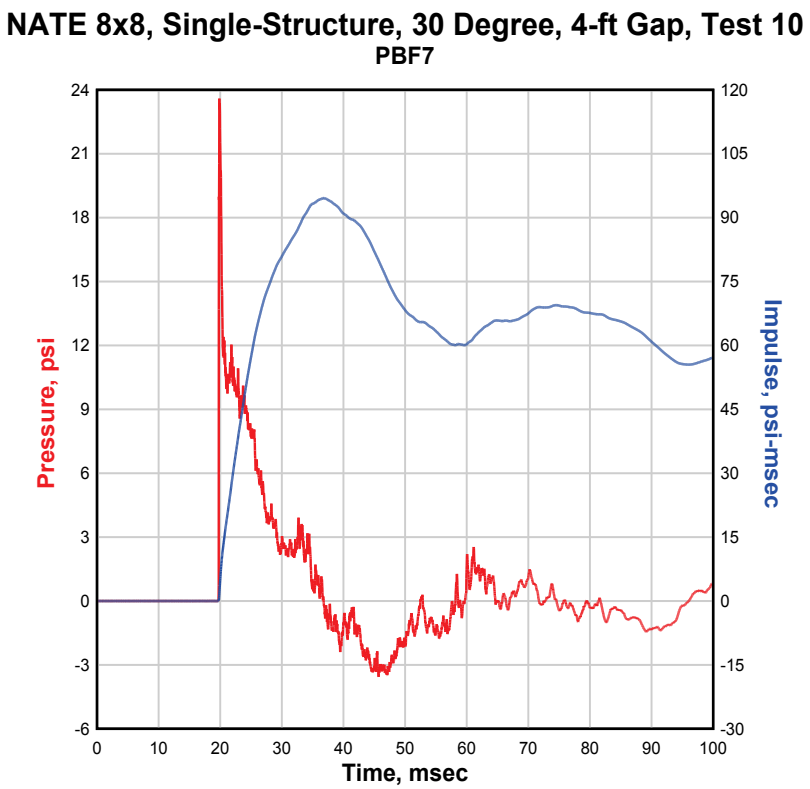

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

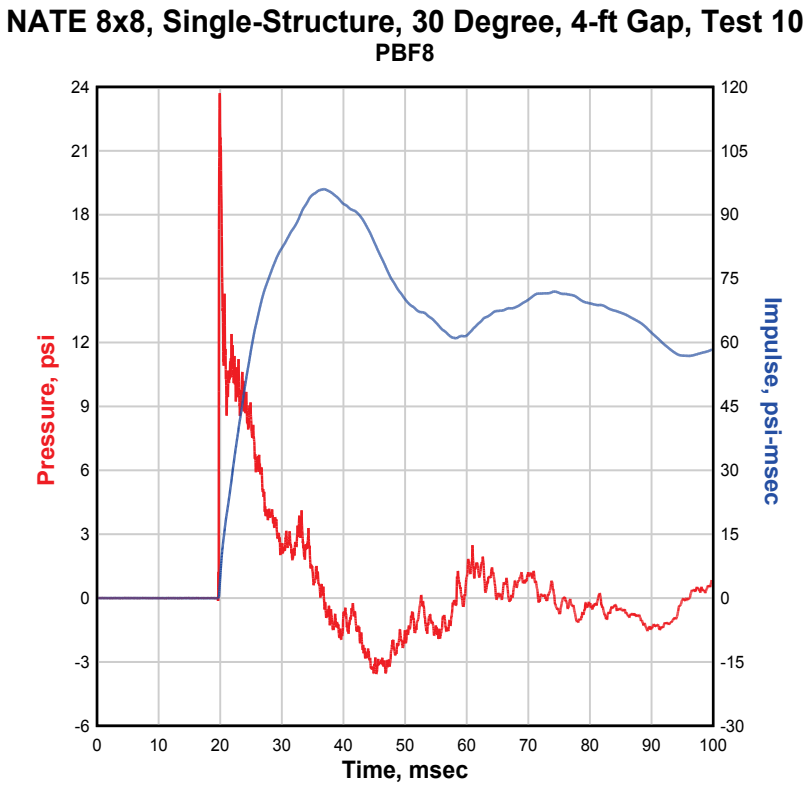

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

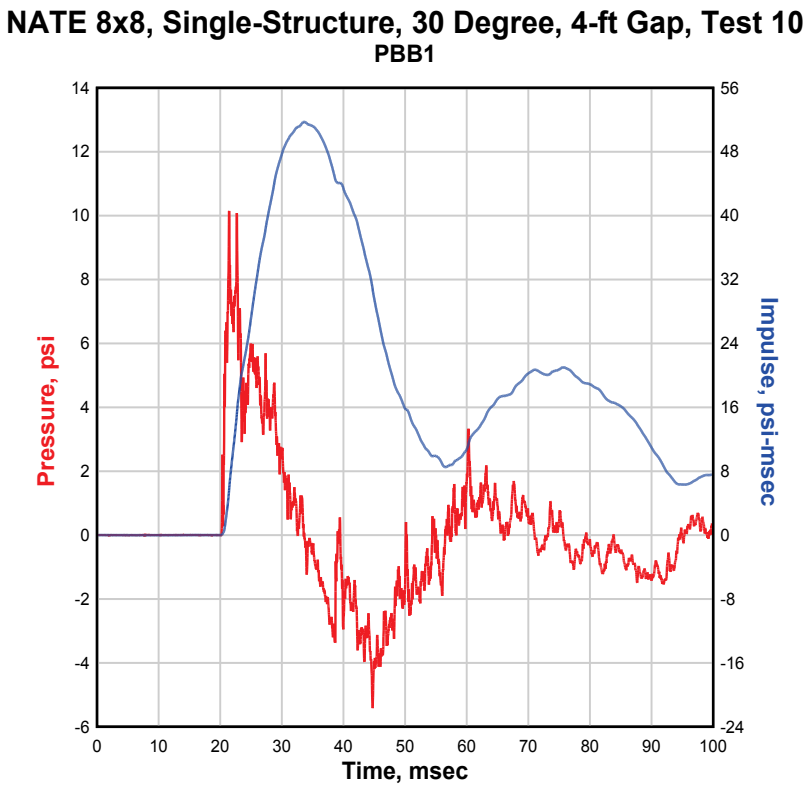

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

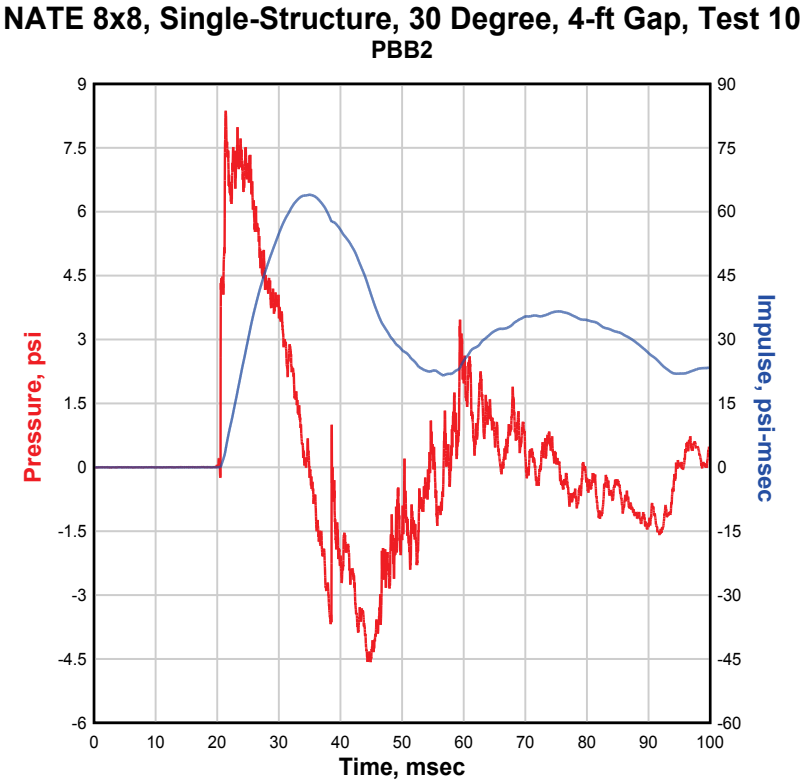

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

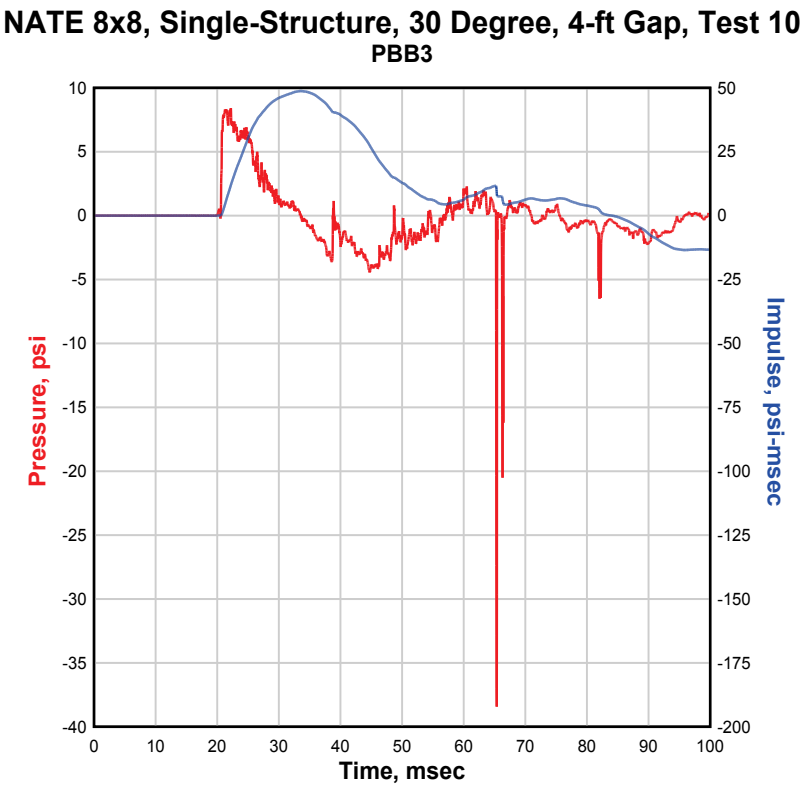

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

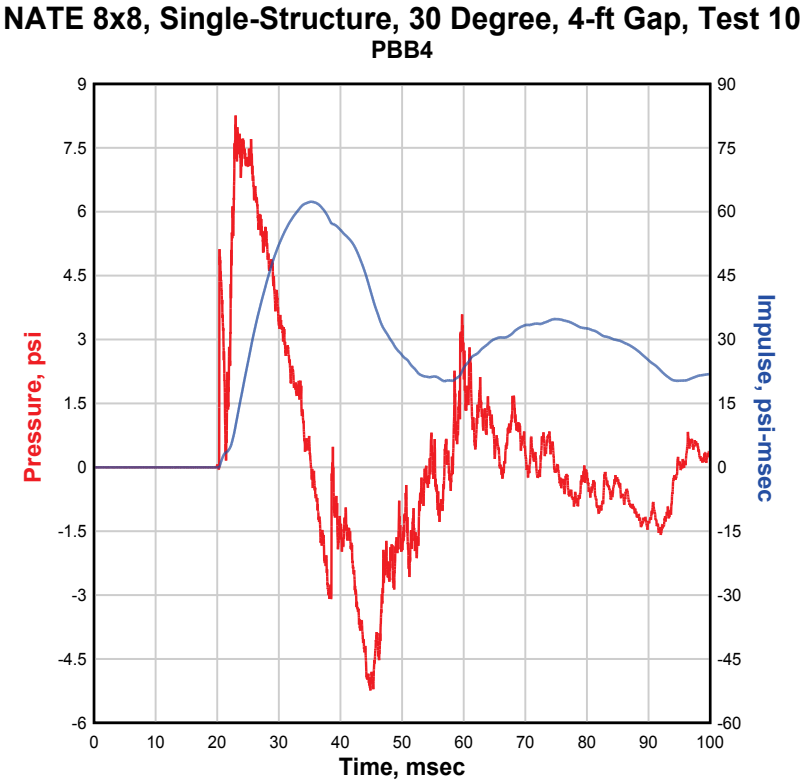

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

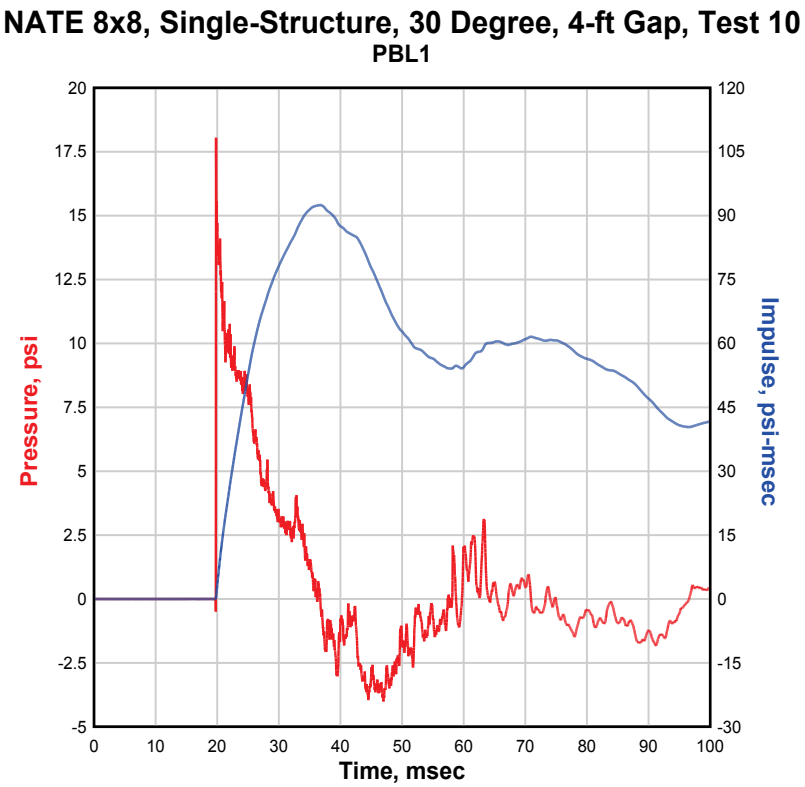

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

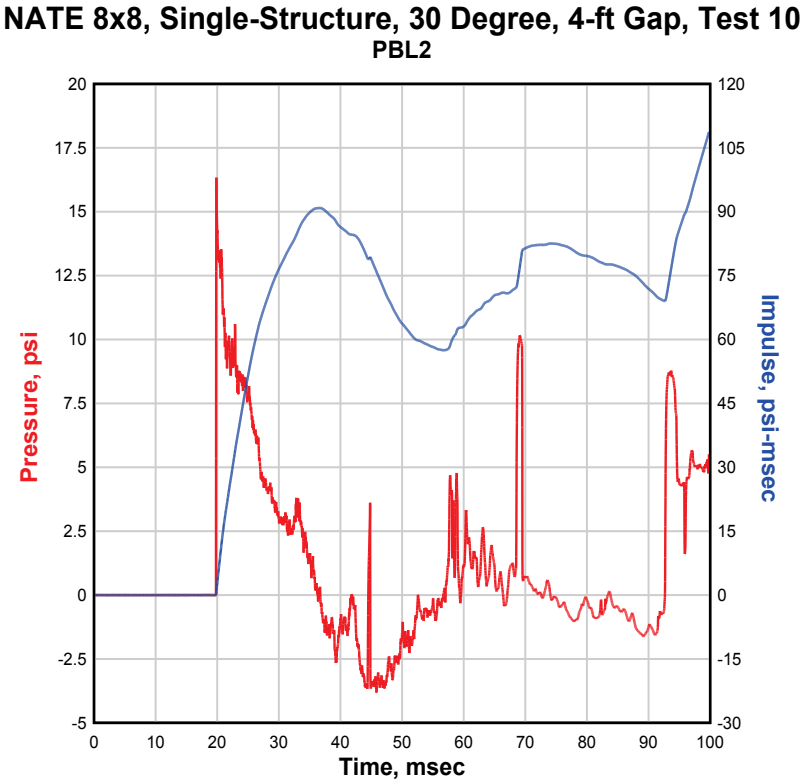

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

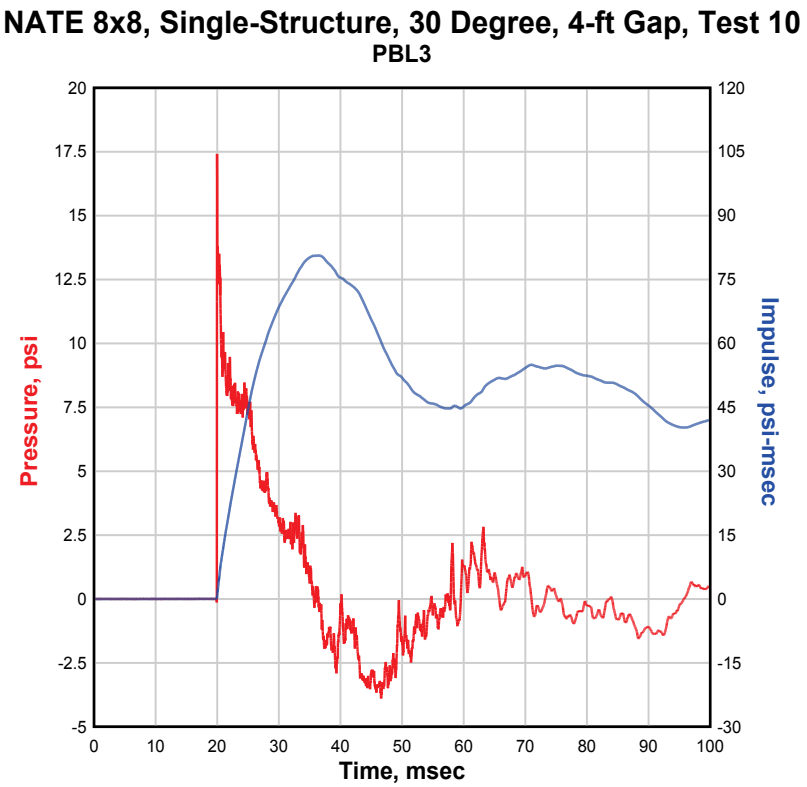

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

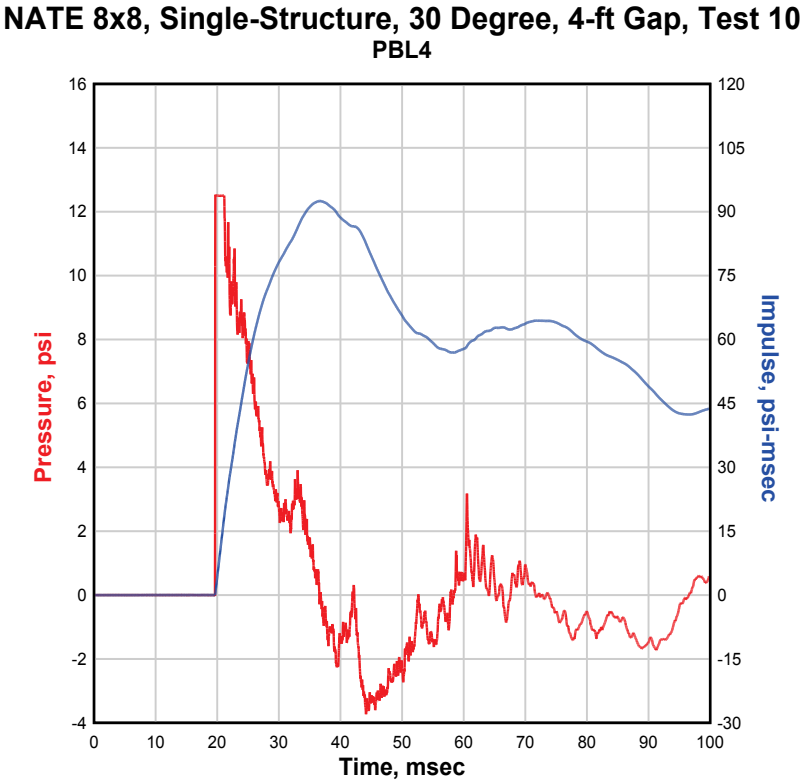

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
50
25
0
-25
-50
-75
-100
-125
-150
-175
-200
0
10
20
30
40
50
60
70
80
90
100

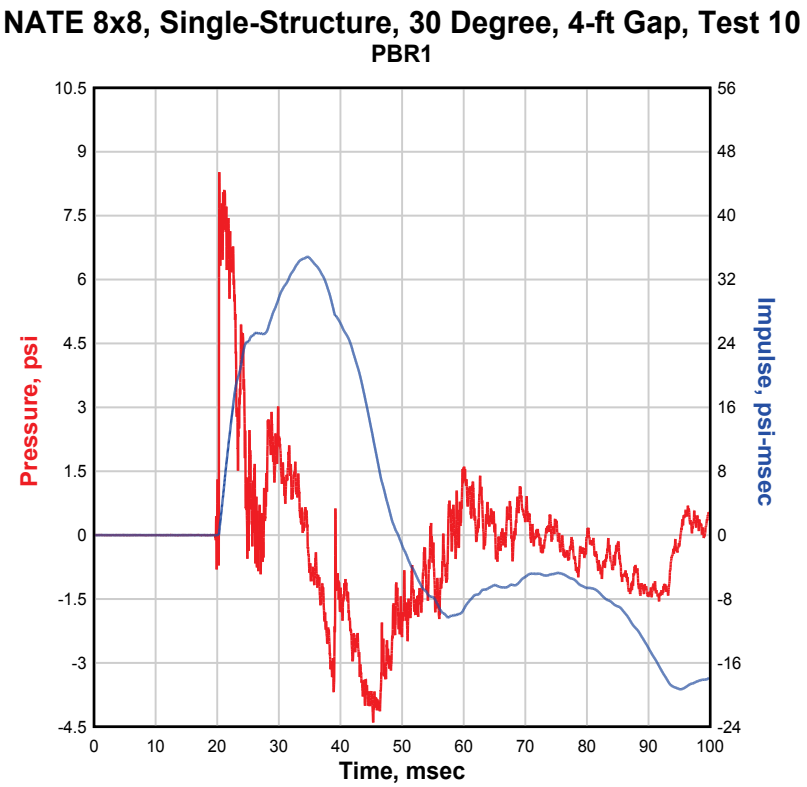

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

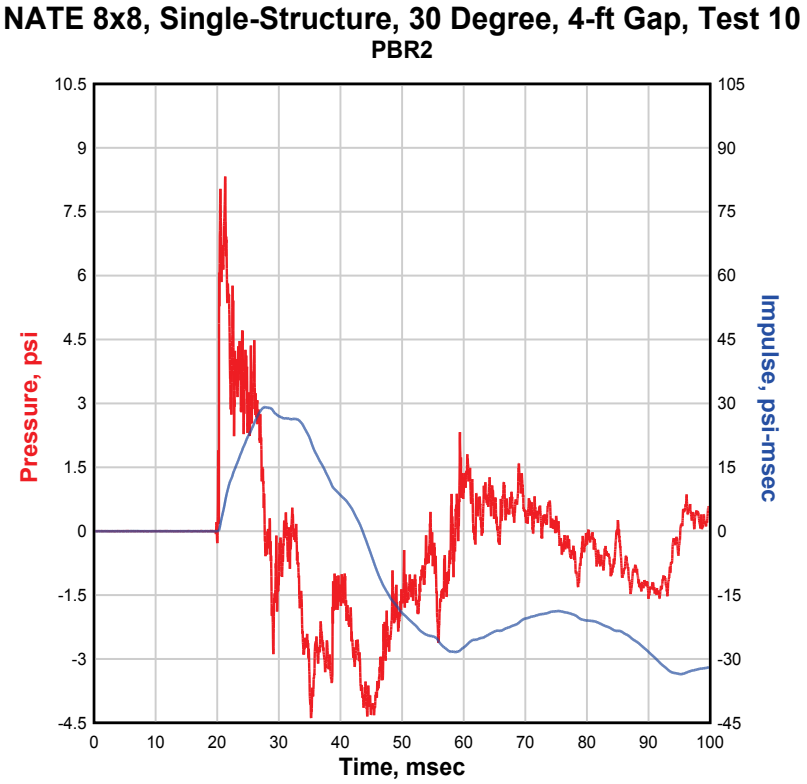

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

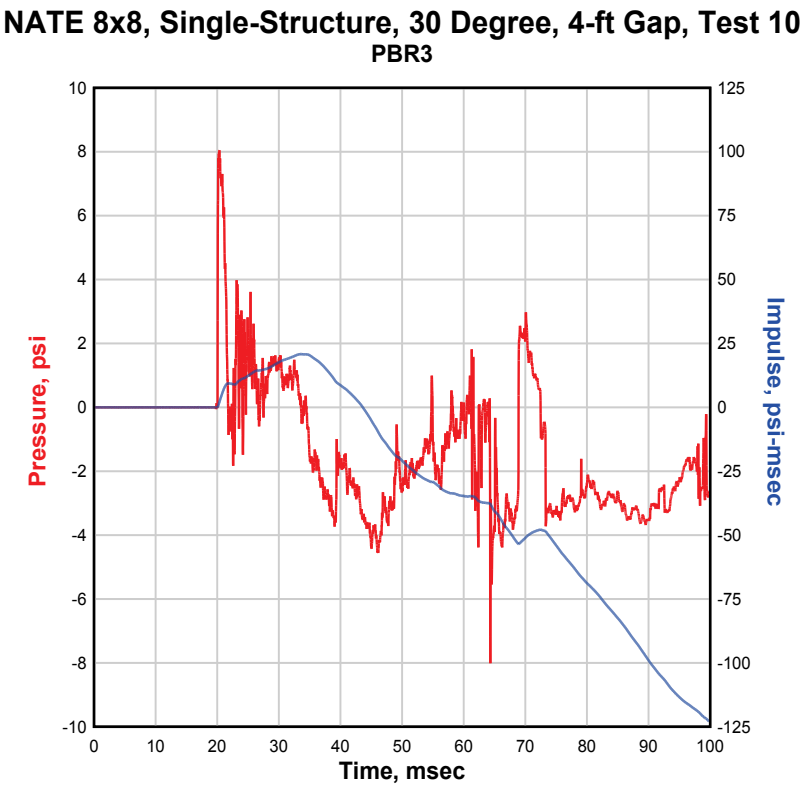

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

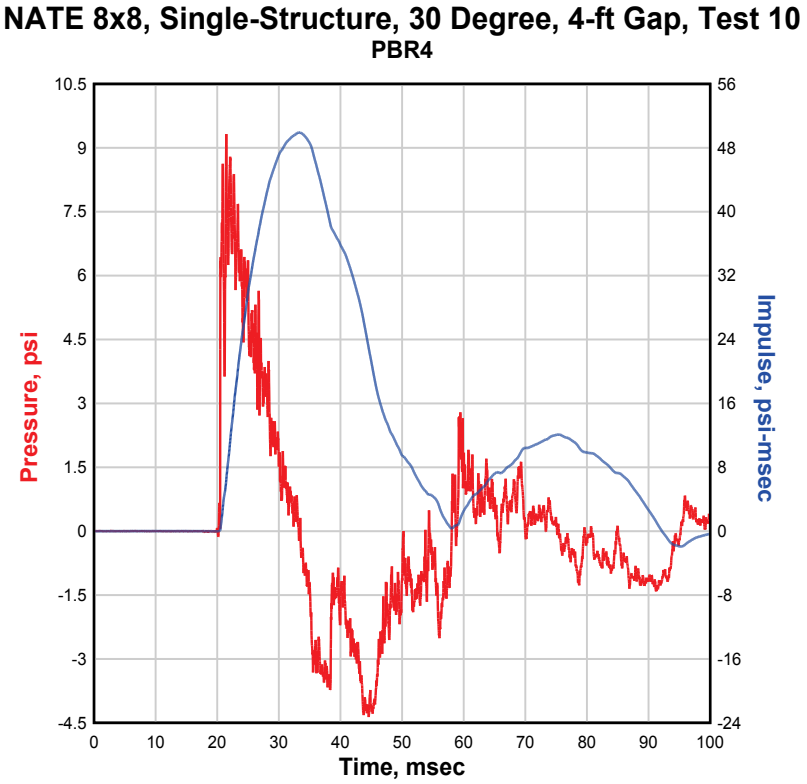

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

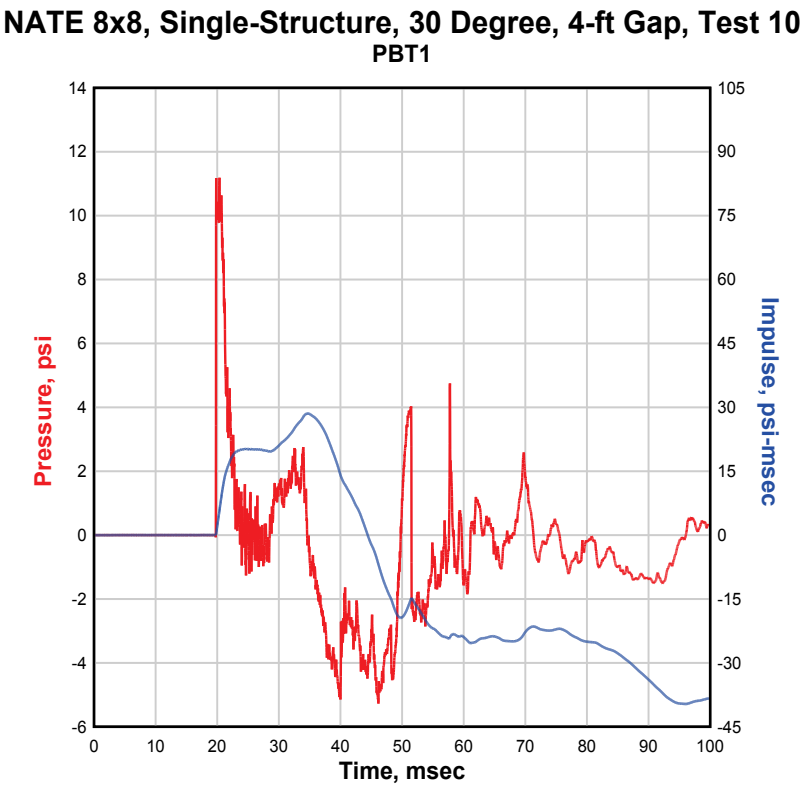

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

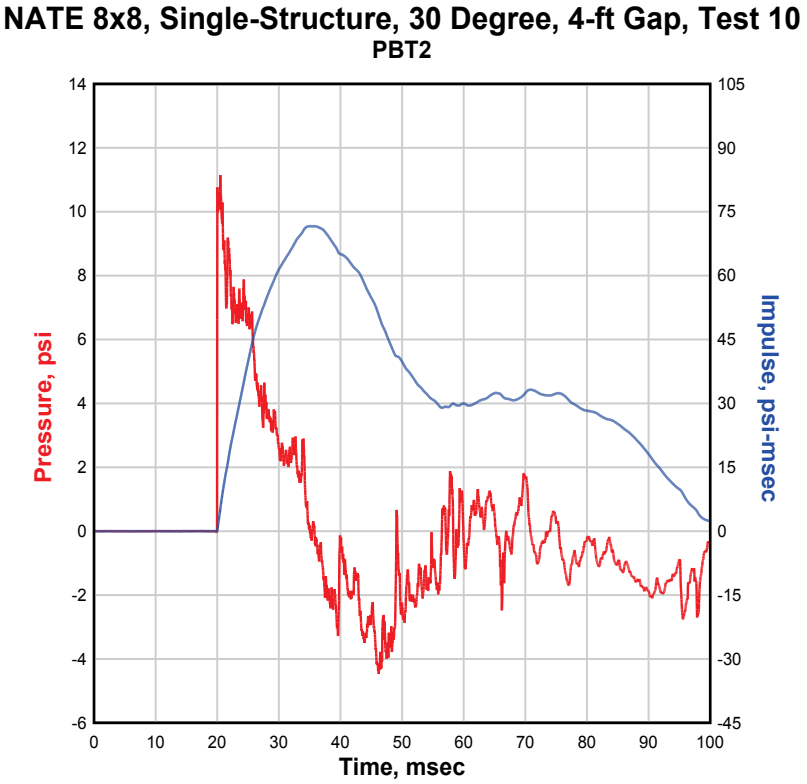

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

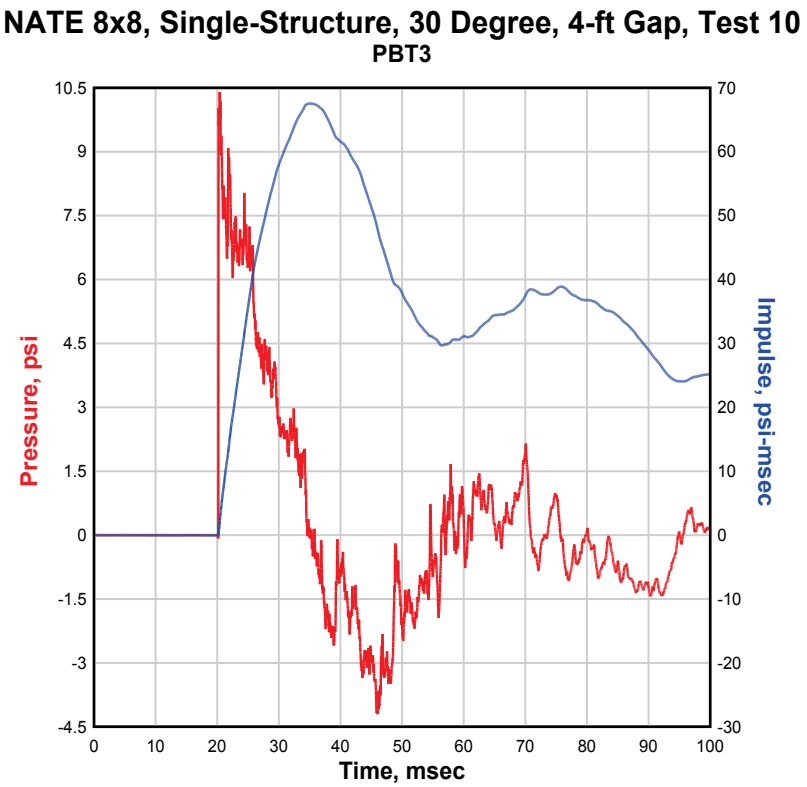

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

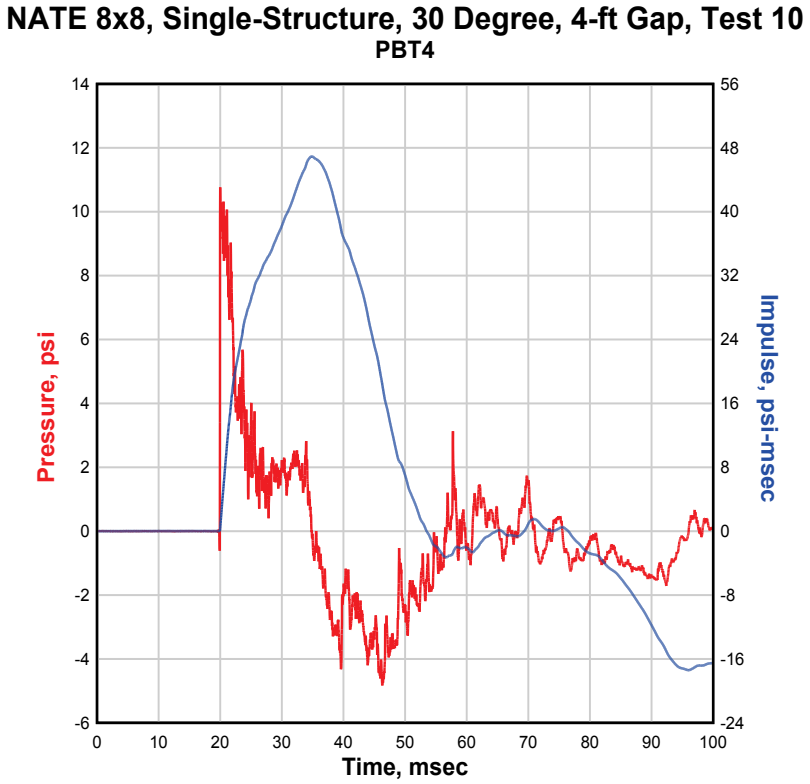

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
10
8
6
4
2
0
-2
-4
-6
-8
-10
125
100
75
50
25
0
-25
-50
-75
-100
-125
0
10
20
30
40
50
60
70
80
90
100

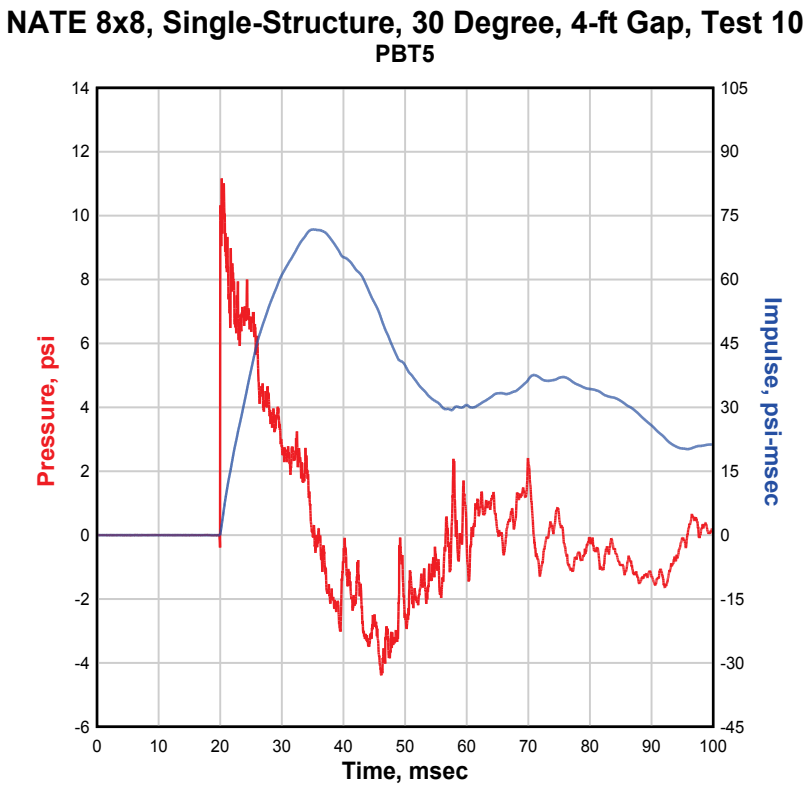

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

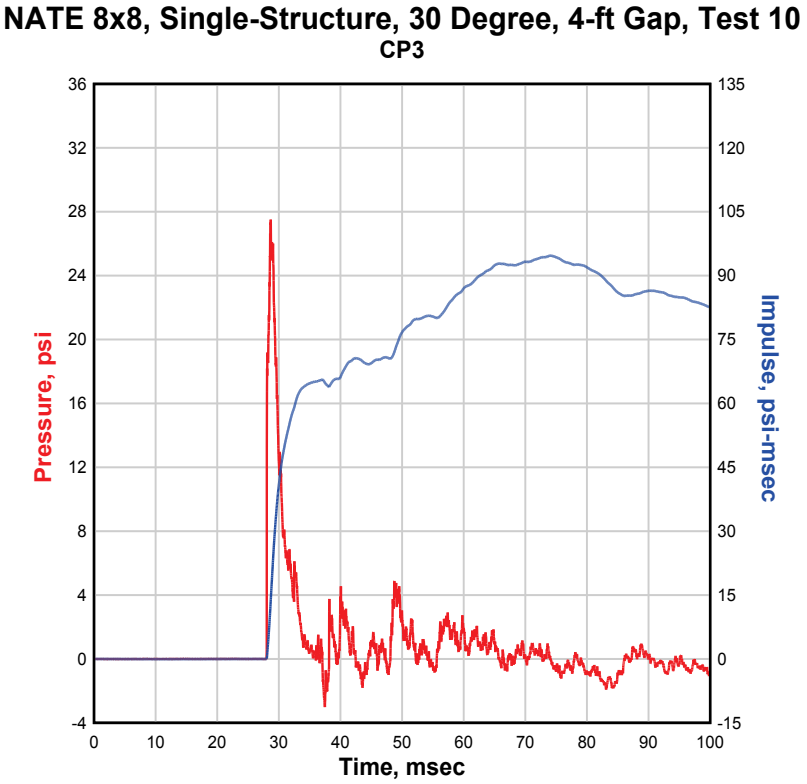

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

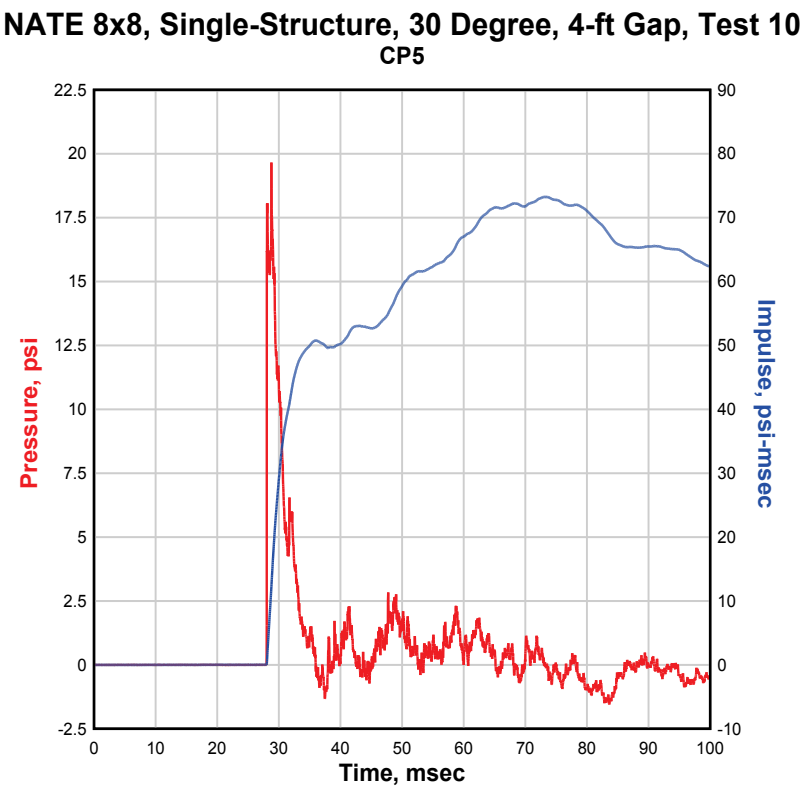

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

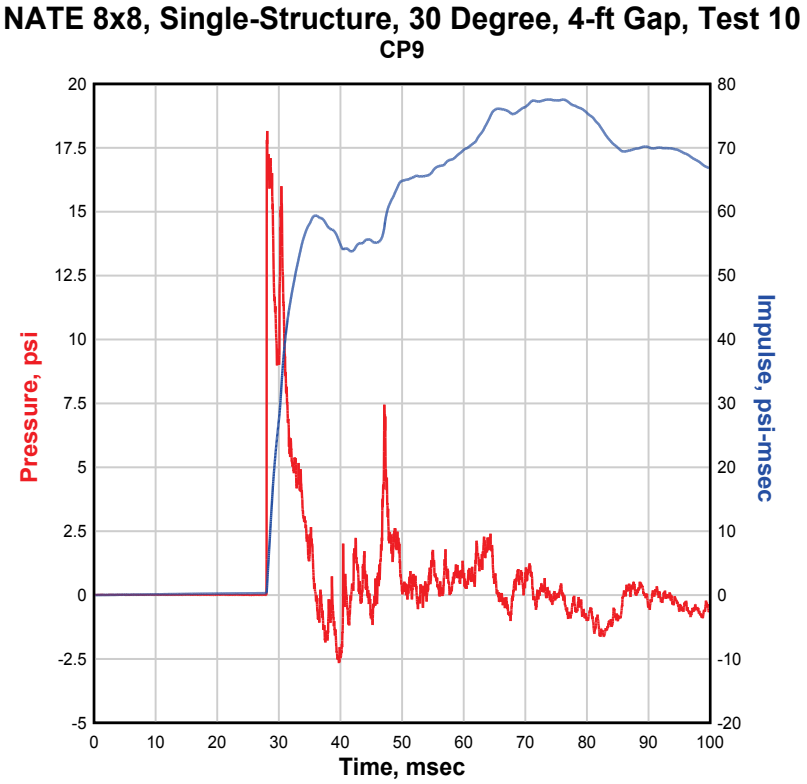

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

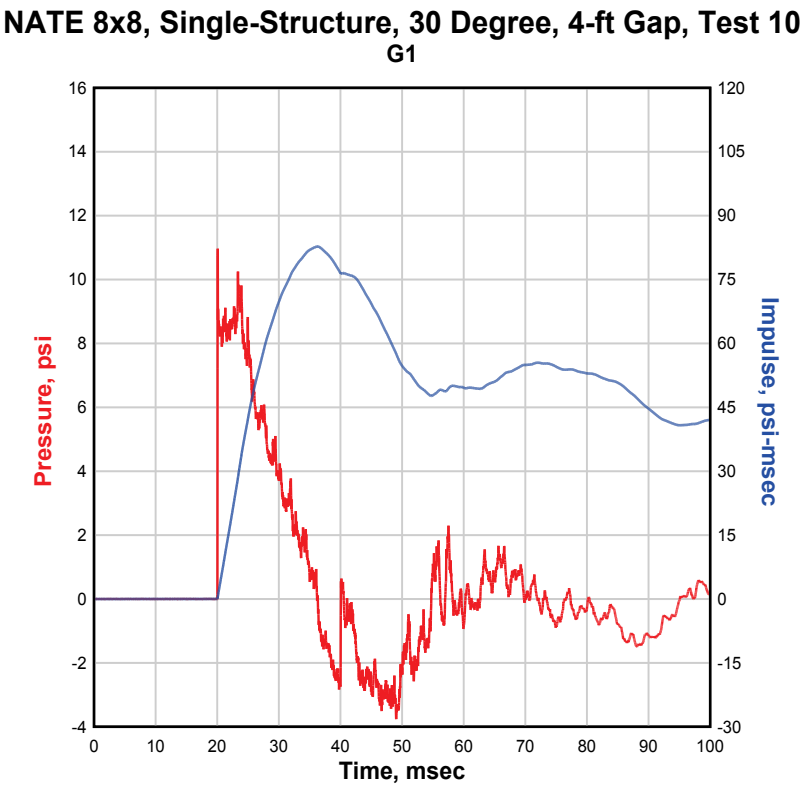

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

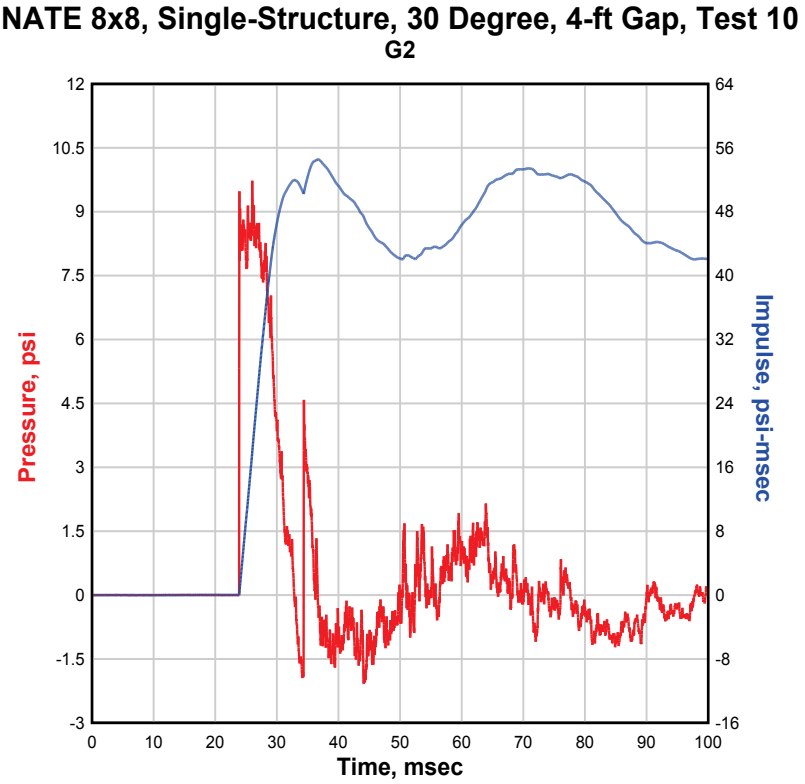

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

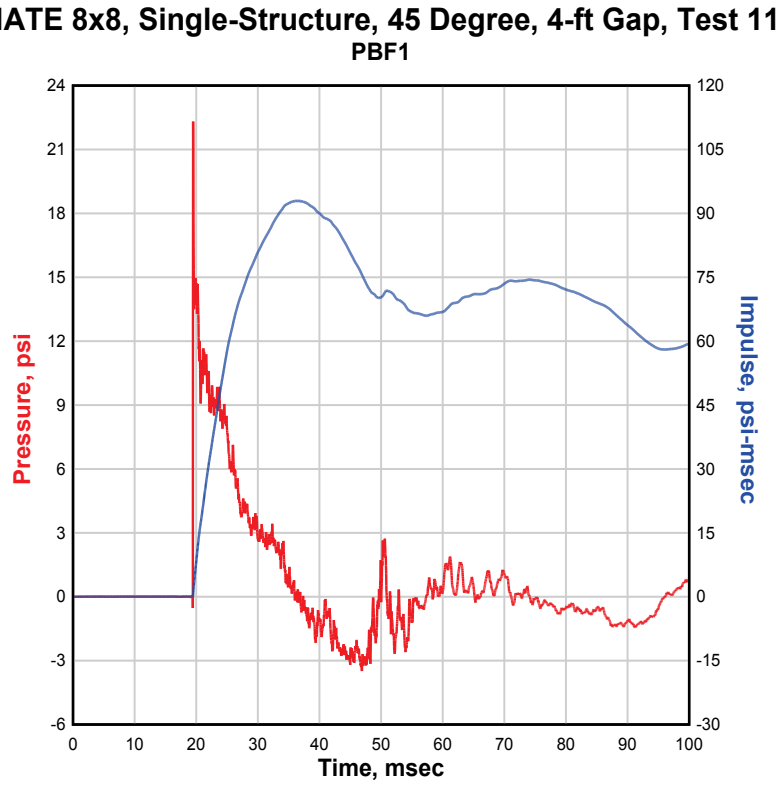

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

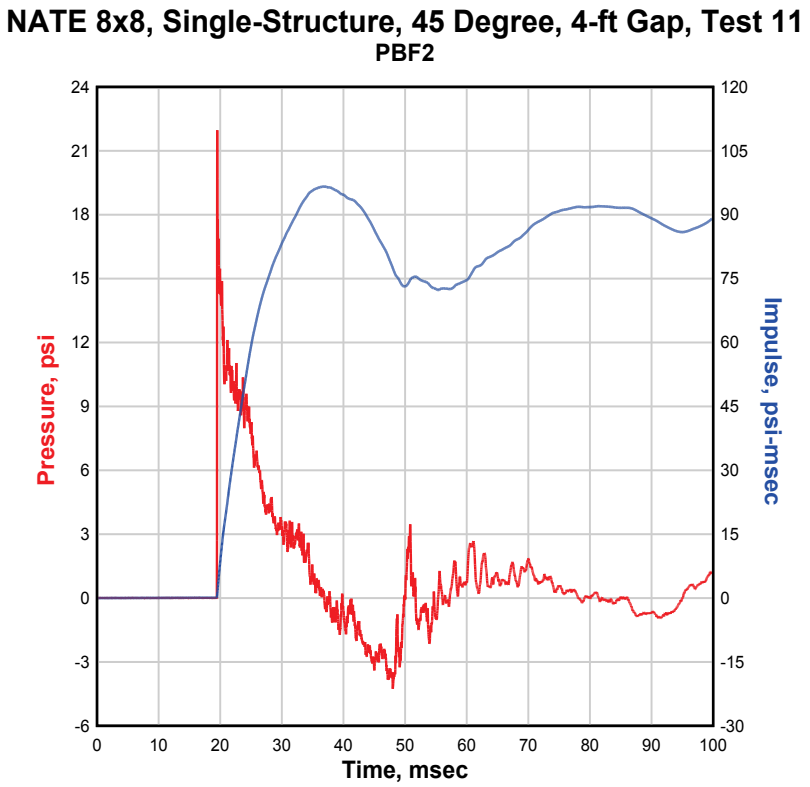

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
80
70
60
50
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100

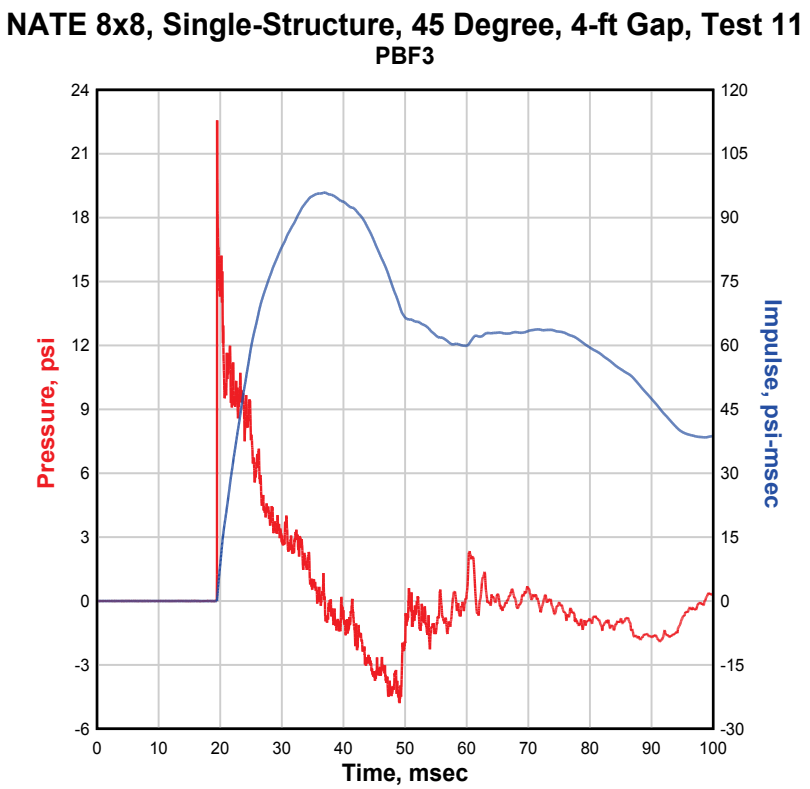

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
G1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

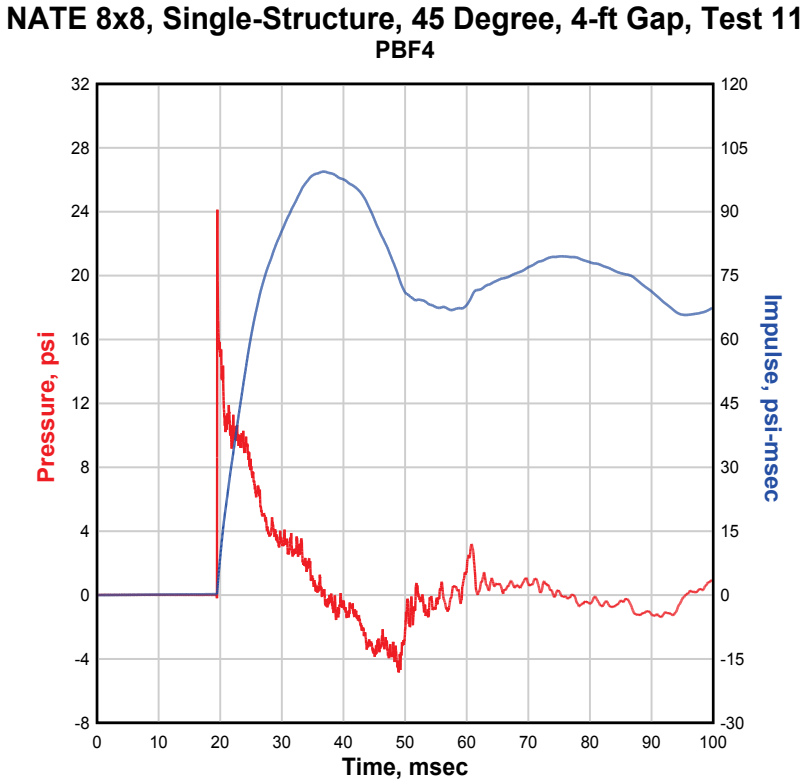

NATE 8x8, Single-Structure, 30 Degree, 4-ft Gap, Test 10
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

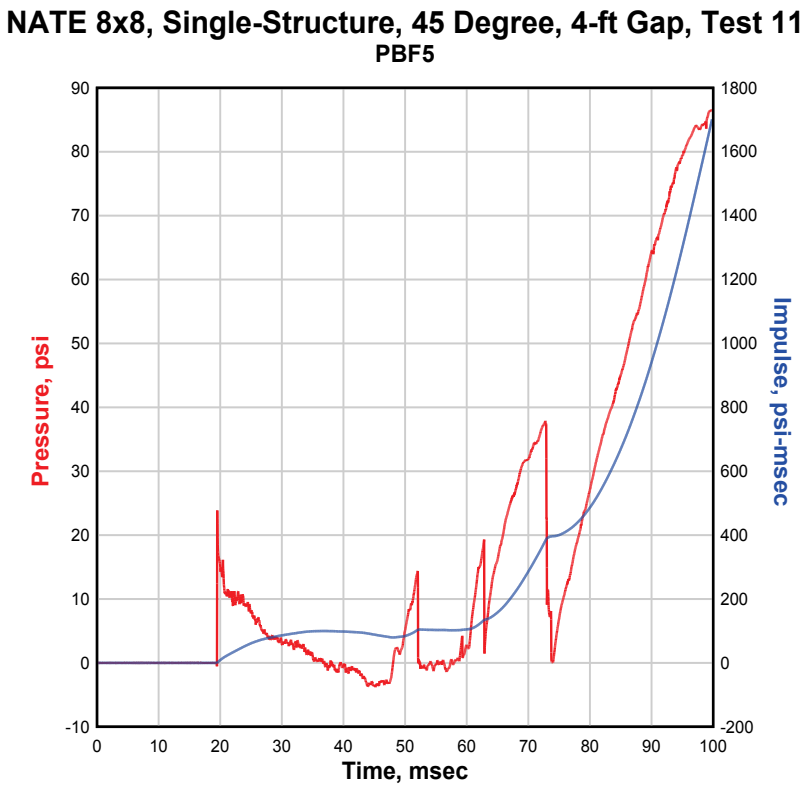
Appendix C: Pressure and Impulse Data from Tests with 45-Degree Obliquity, 4-ft Gap

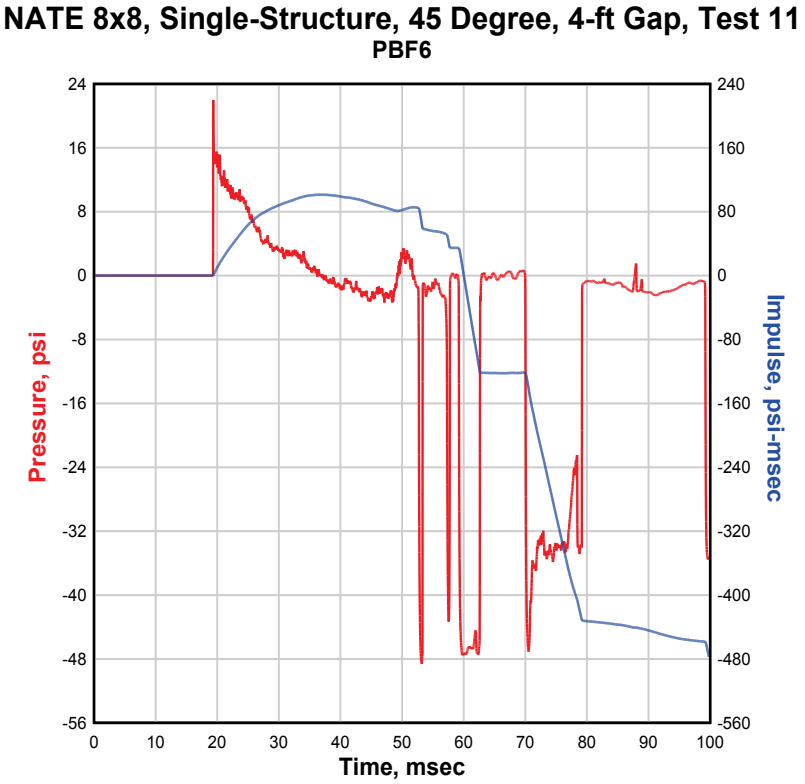


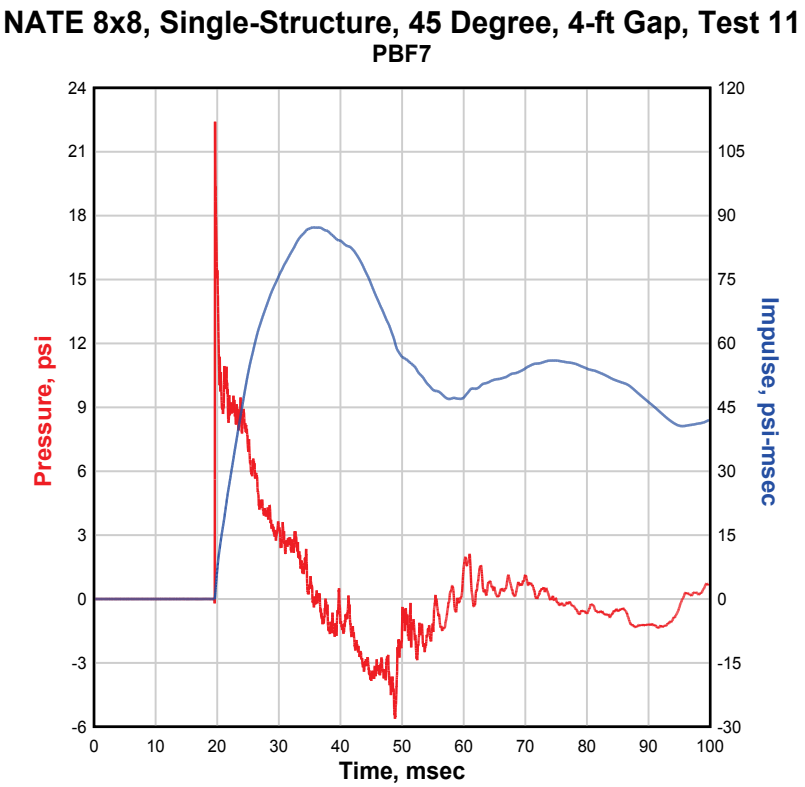

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

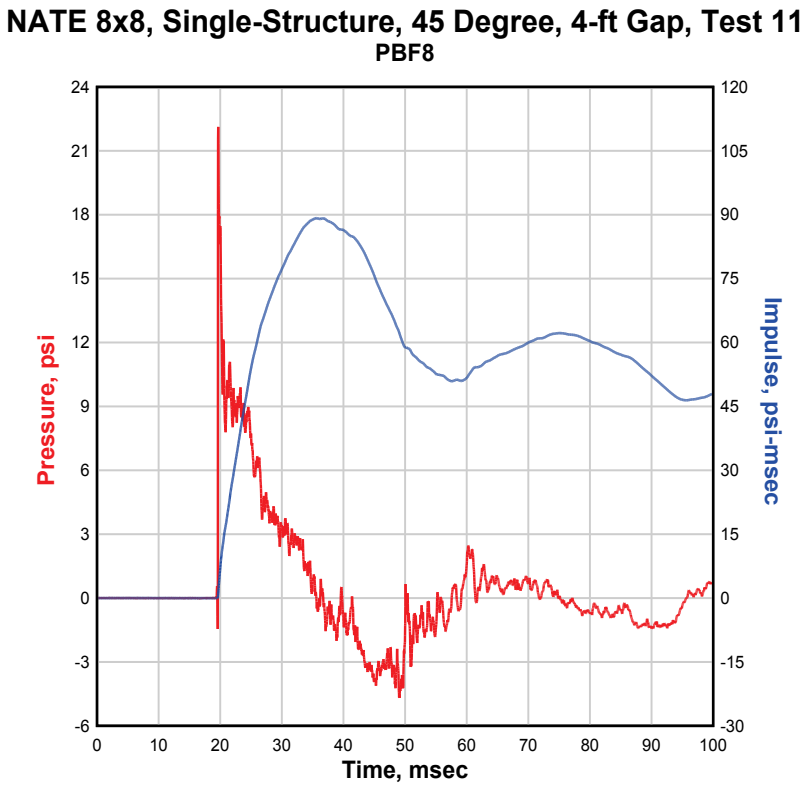

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

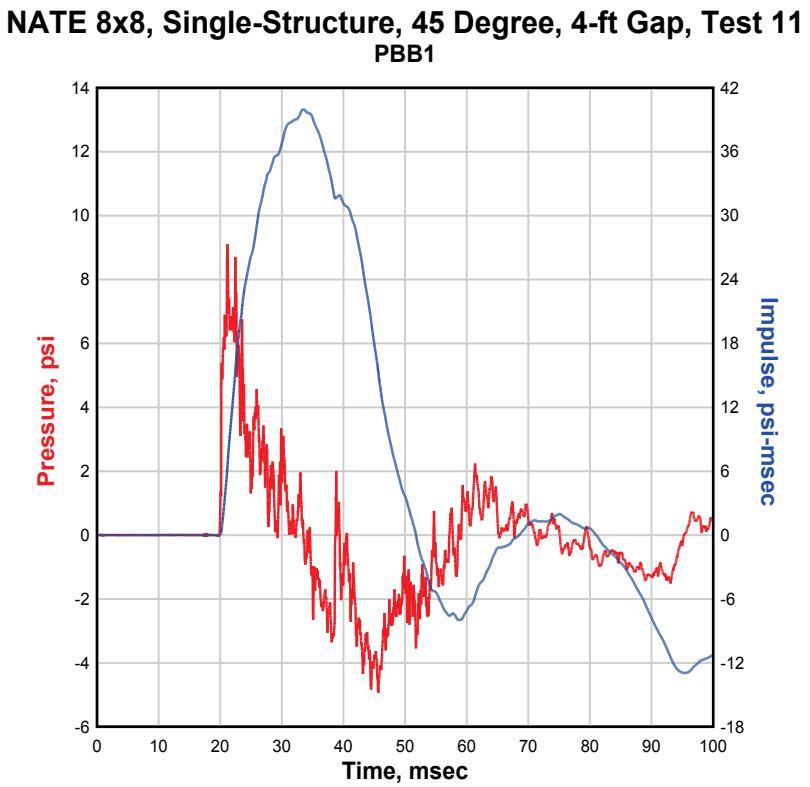

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

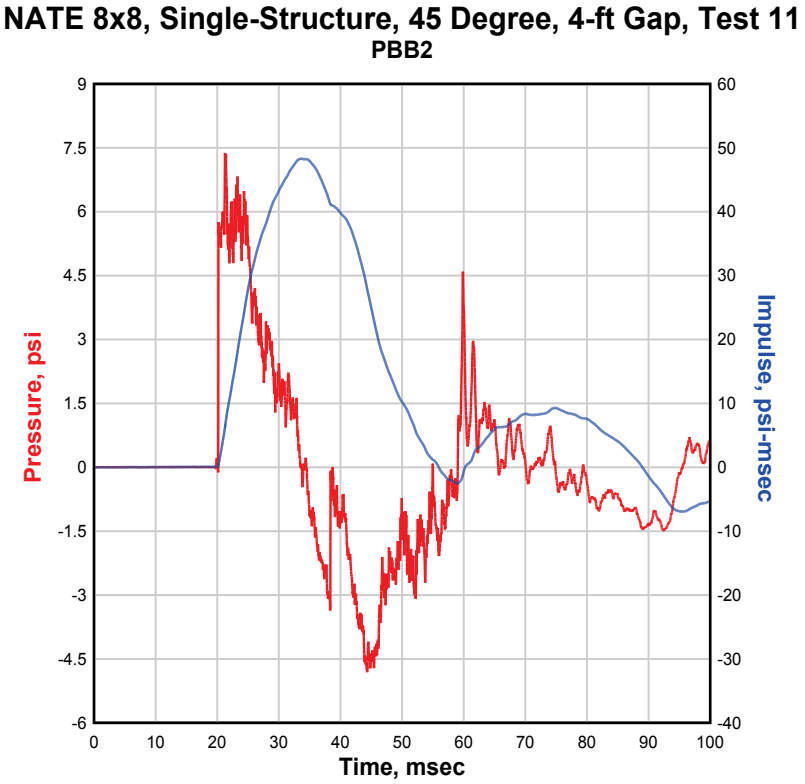

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
90
80
70
60
50
40
30
20
10
0
-10
1800
1600
1400
1200
1000
800
600
400
200
0
-200
0
10
20
30
40
50
60
70
80
90
100

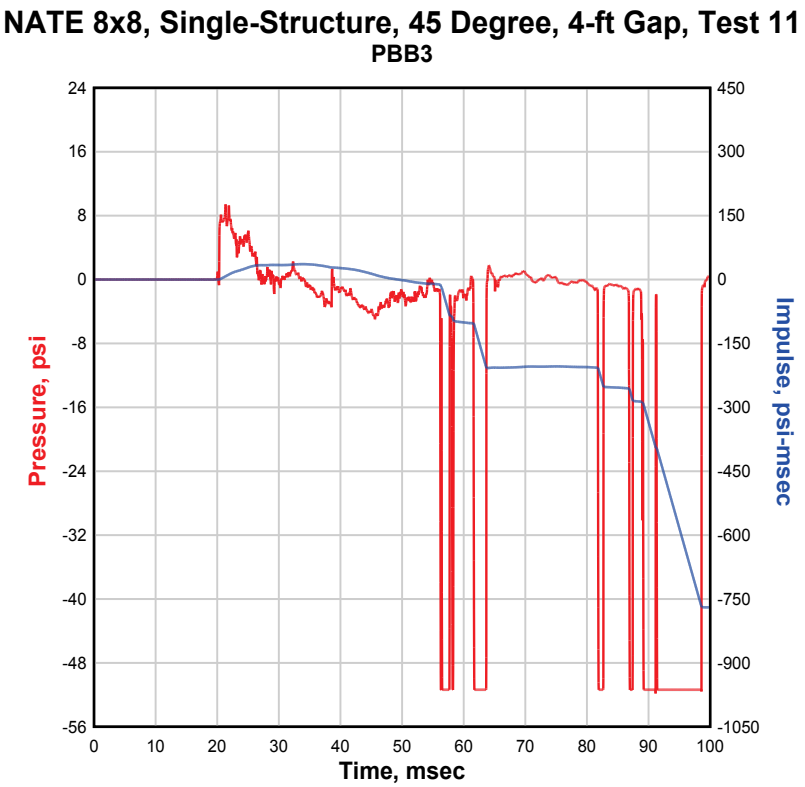

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
240
160
80
0
-80
-160
-240
-320
-400
-480
-560
0
10
20
30
40
50
60
70
80
90
100

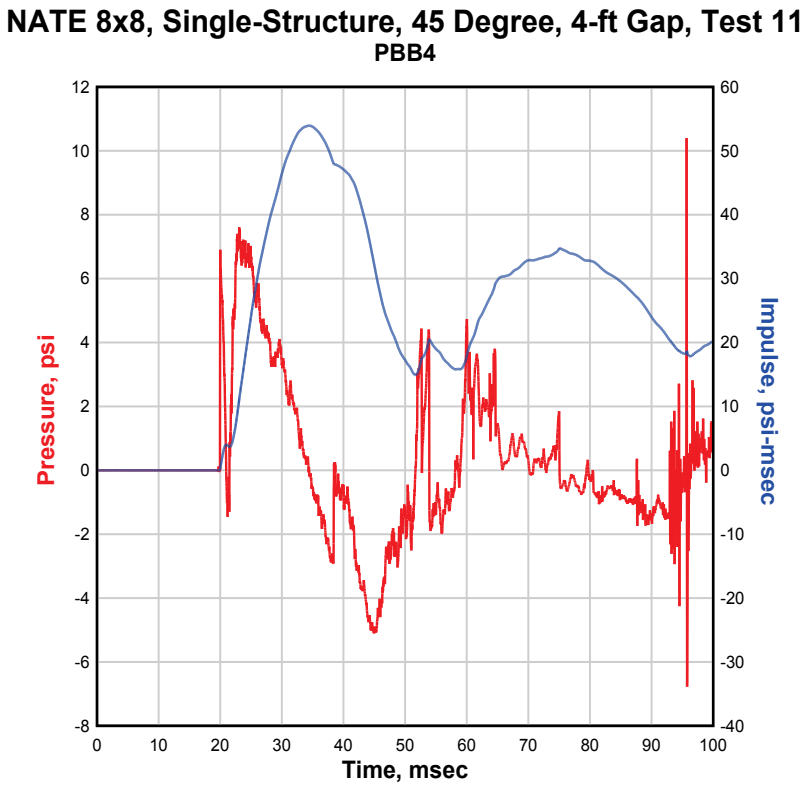

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

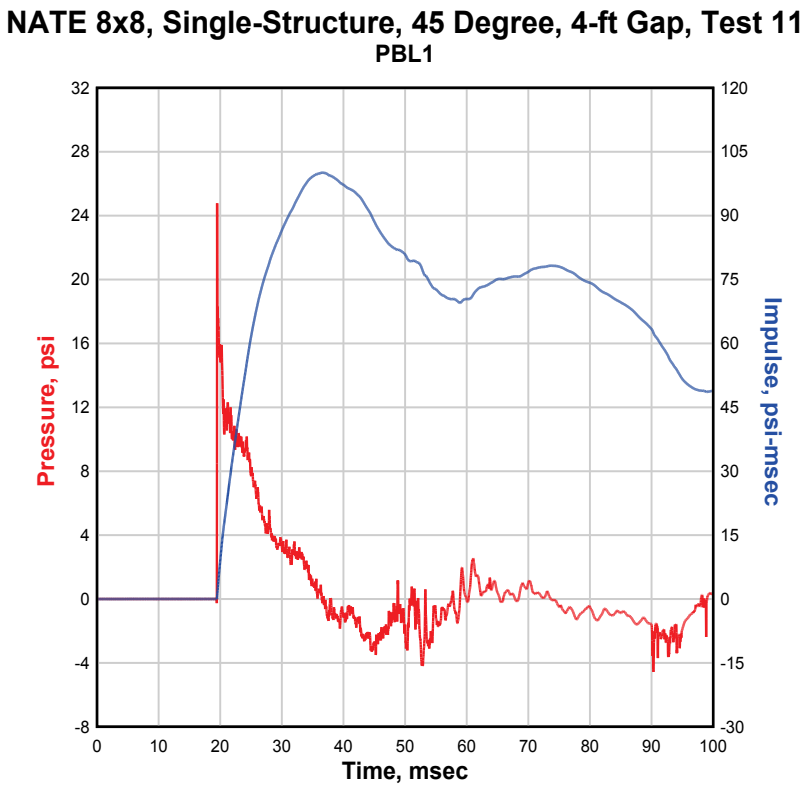

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

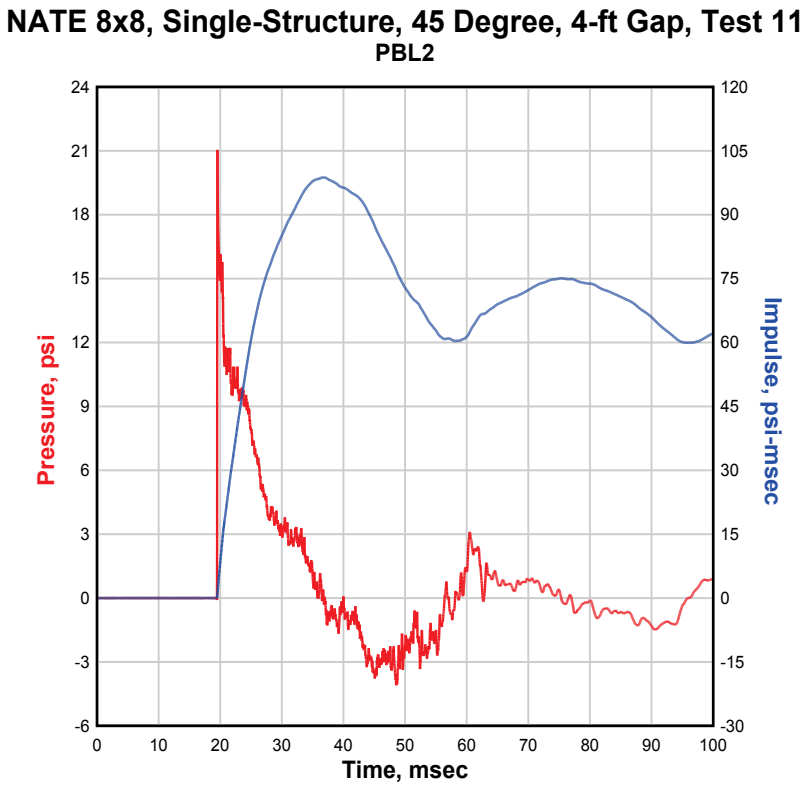

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
42
36
30
24
18
12
6
0
-6
-12
-18
0
10
20
30
40
50
60
70
80
90
100

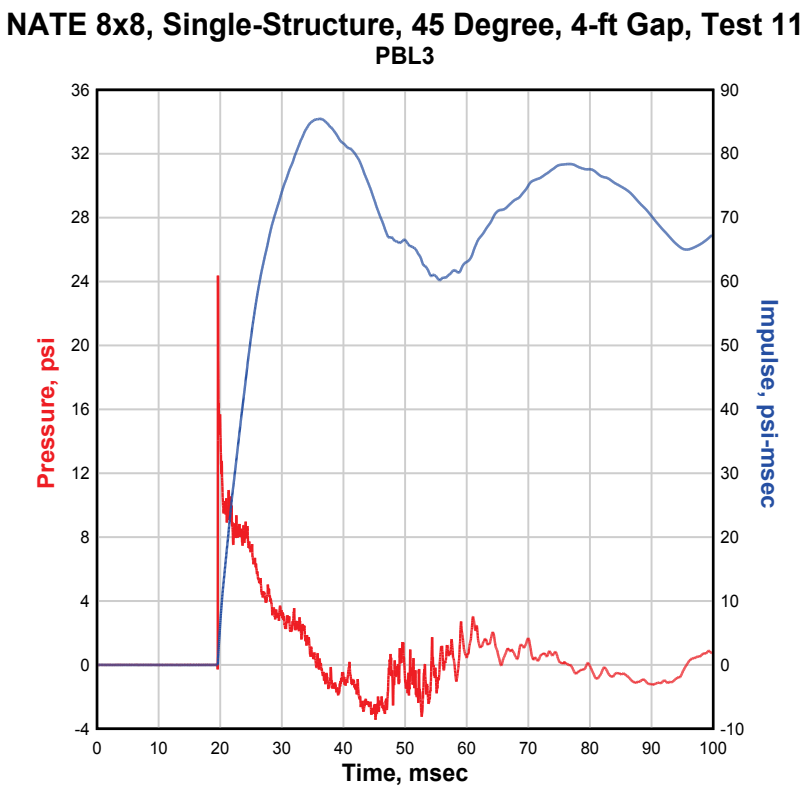

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100

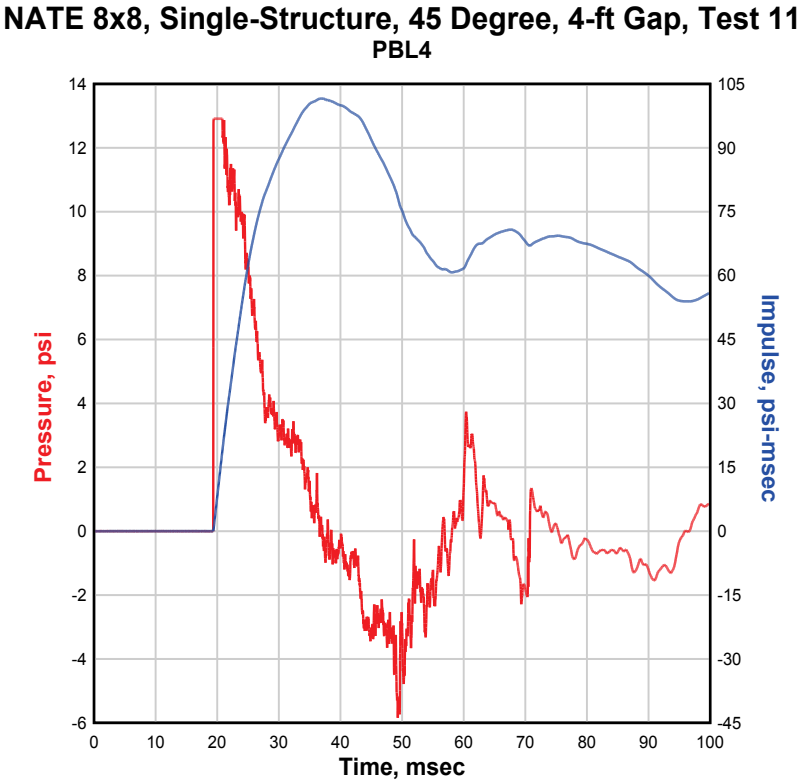

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
450
300
150
0
-150
-300
-450
-600
-750
-900
-1050
0
10
20
30
40
50
60
70
80
90
100

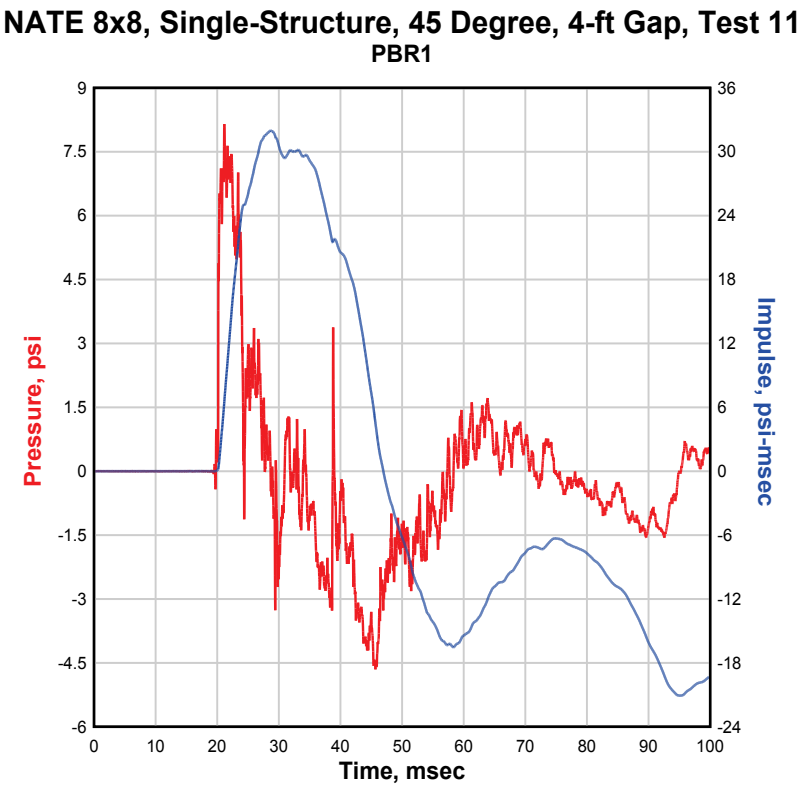

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100

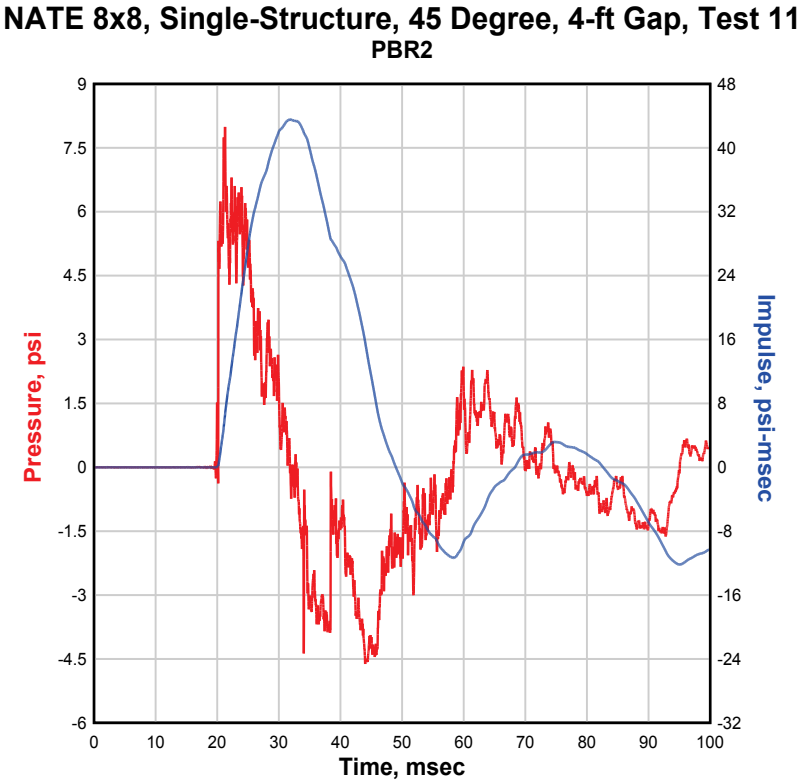

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

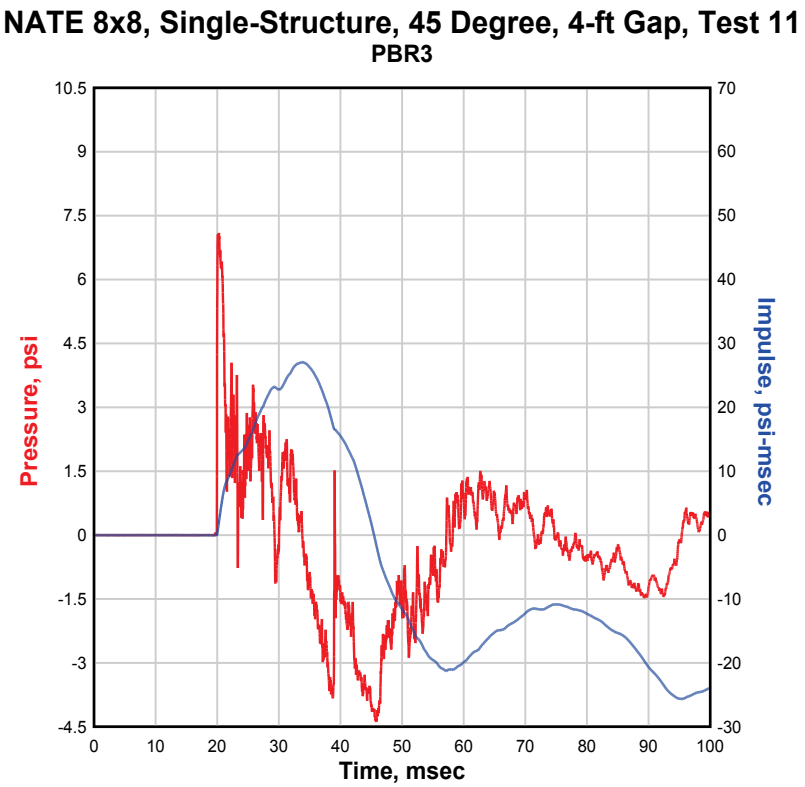

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

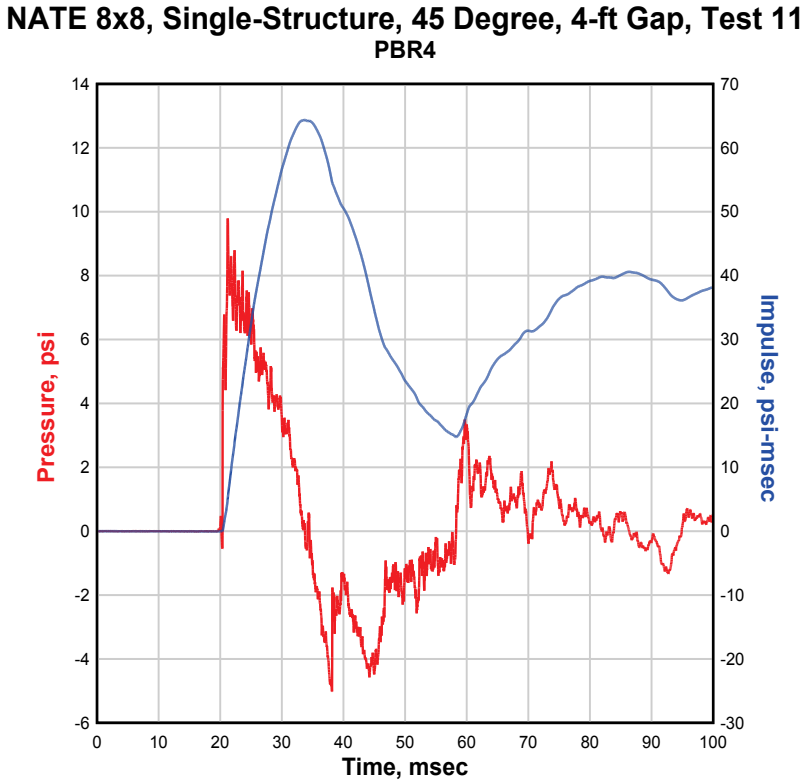

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

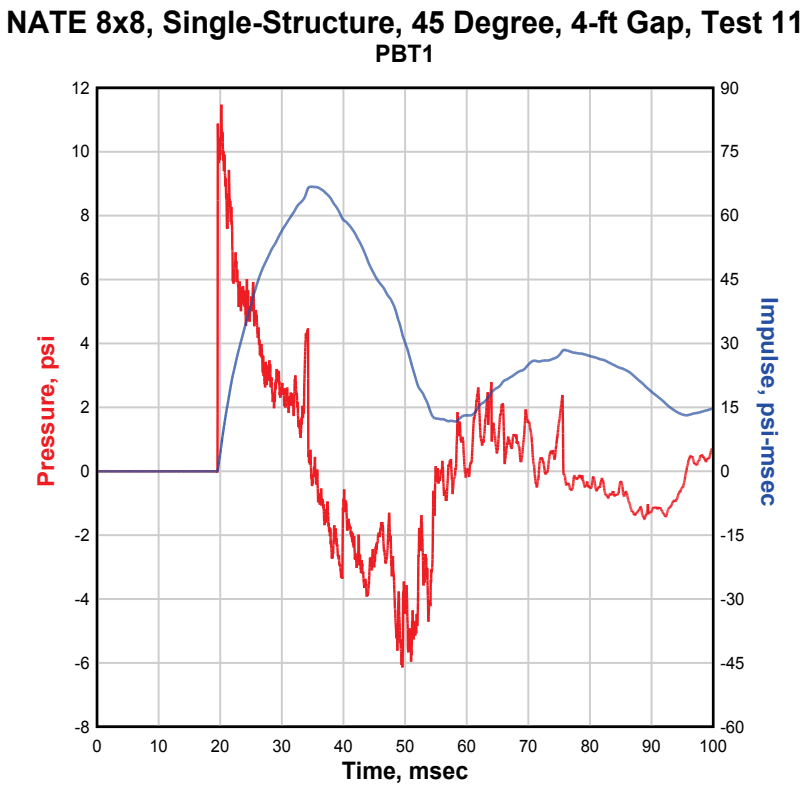

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

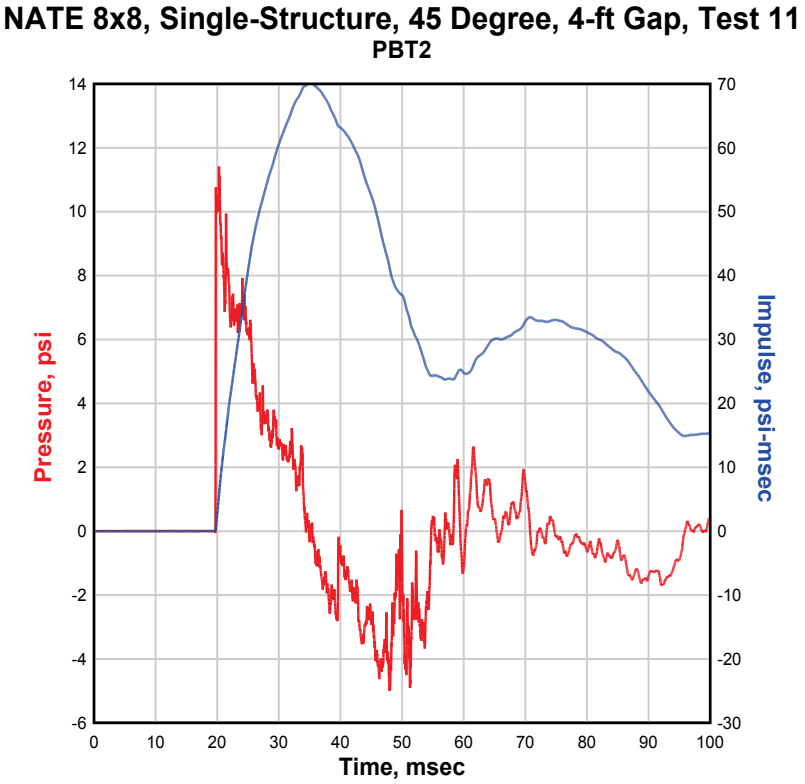

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
36
30
24
18
12
6
0
-6
-12
-18
-24
0
10
20
30
40
50
60
70
80
90
100

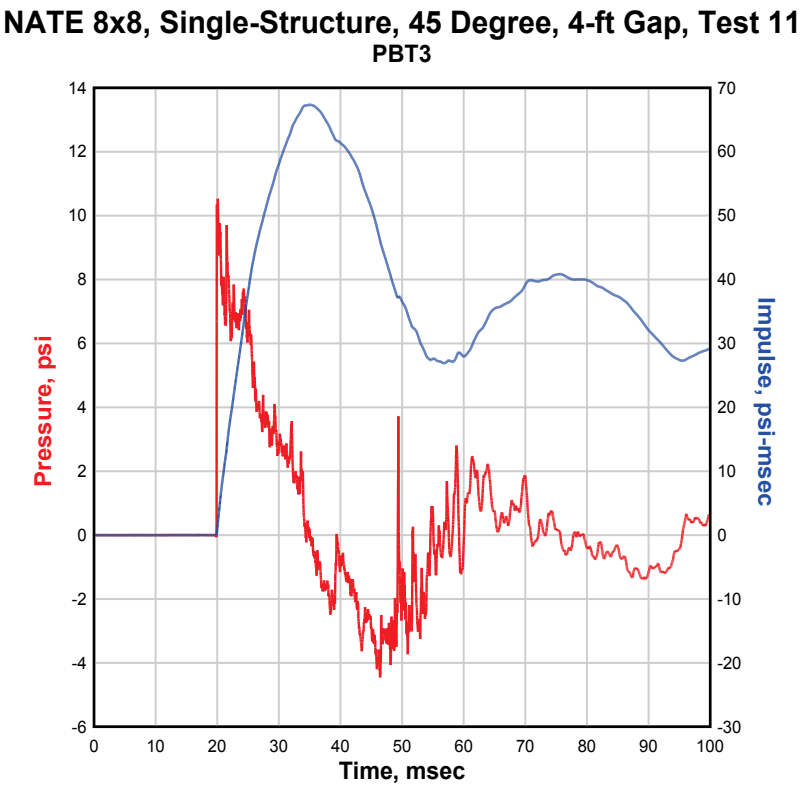

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100

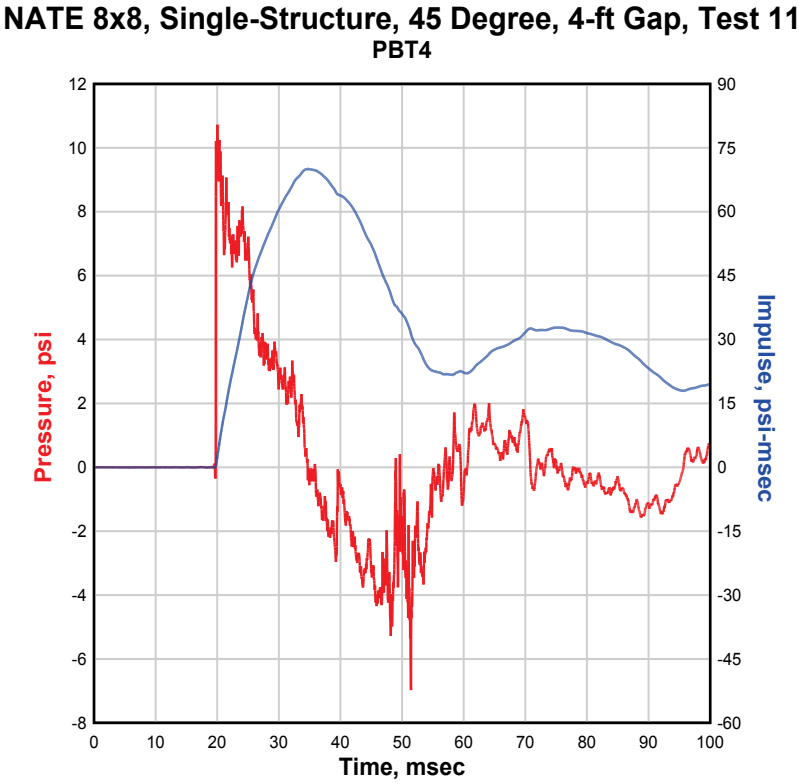

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

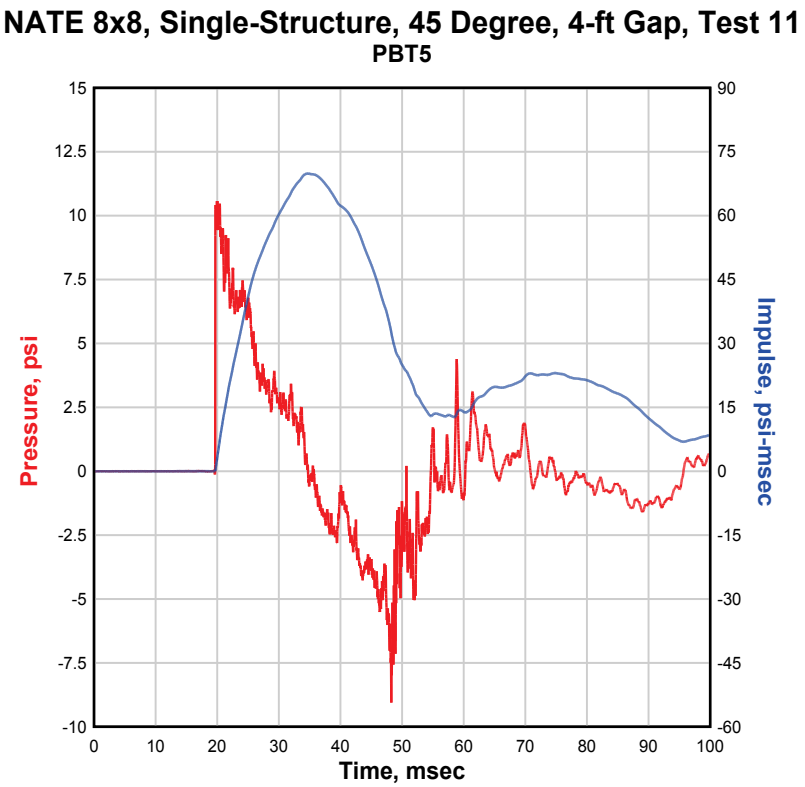

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

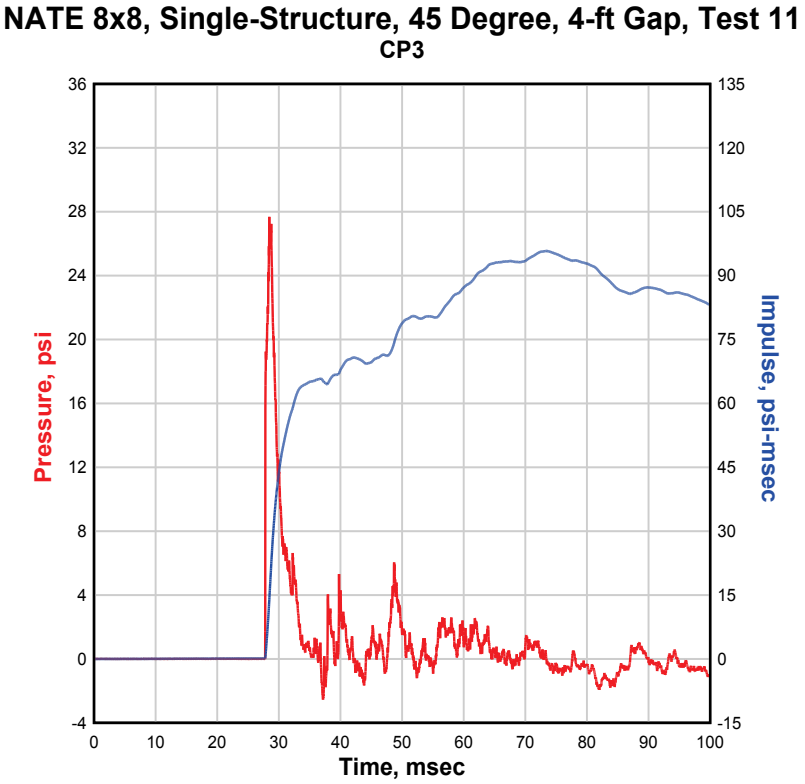

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

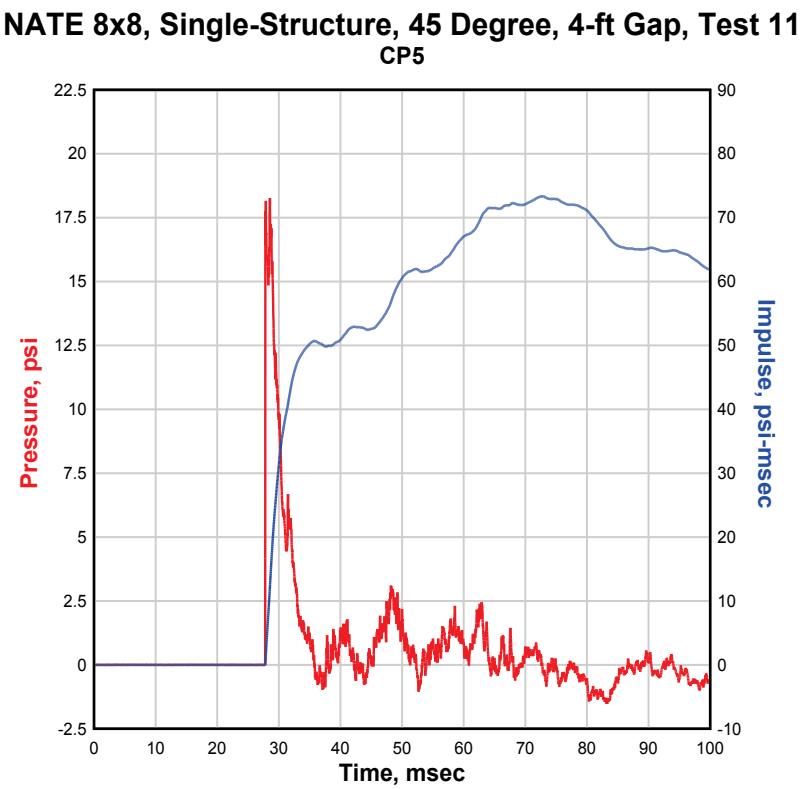

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

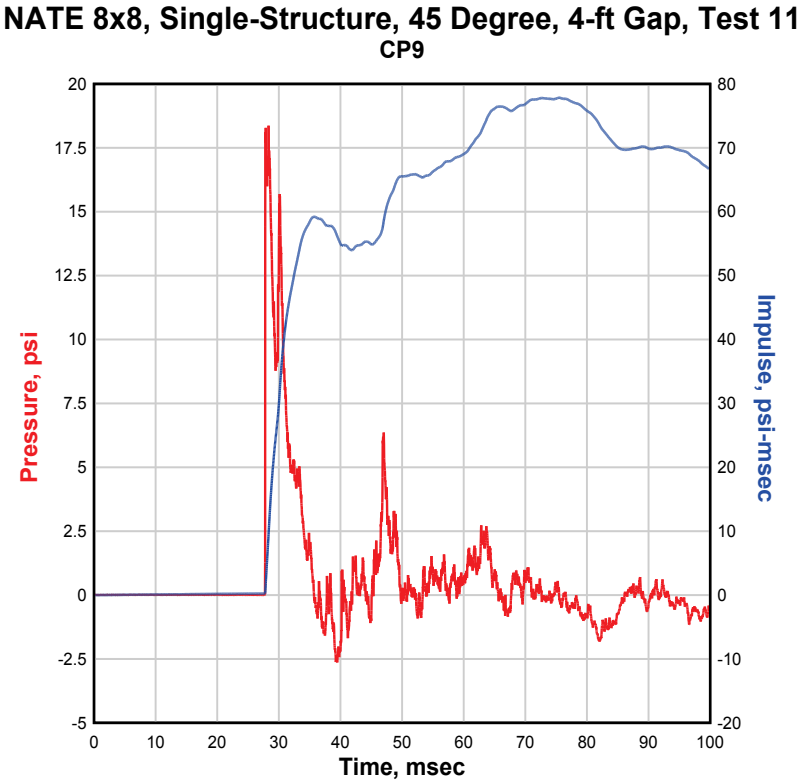

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

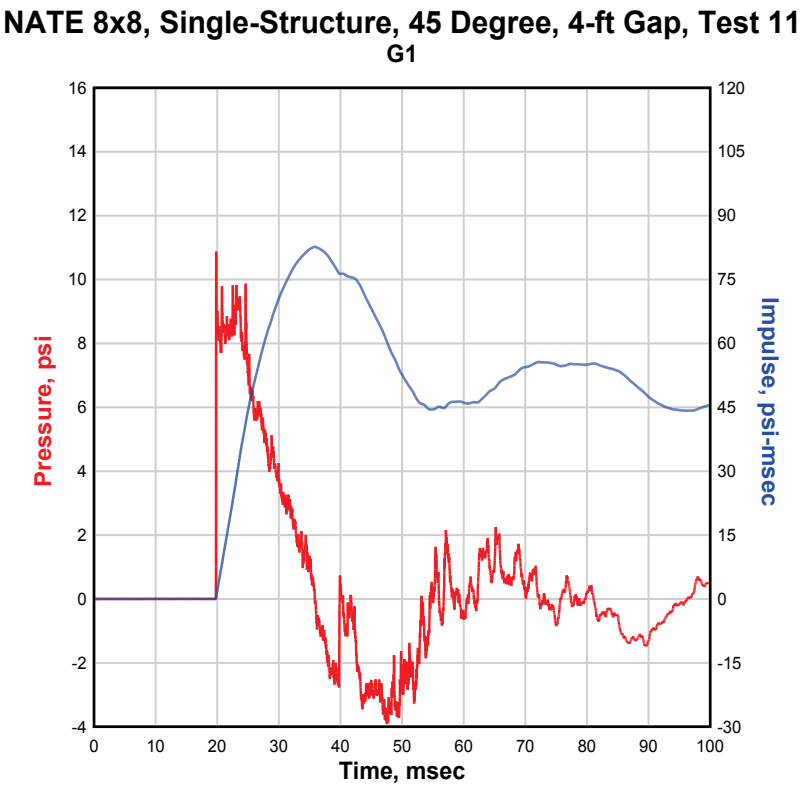

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

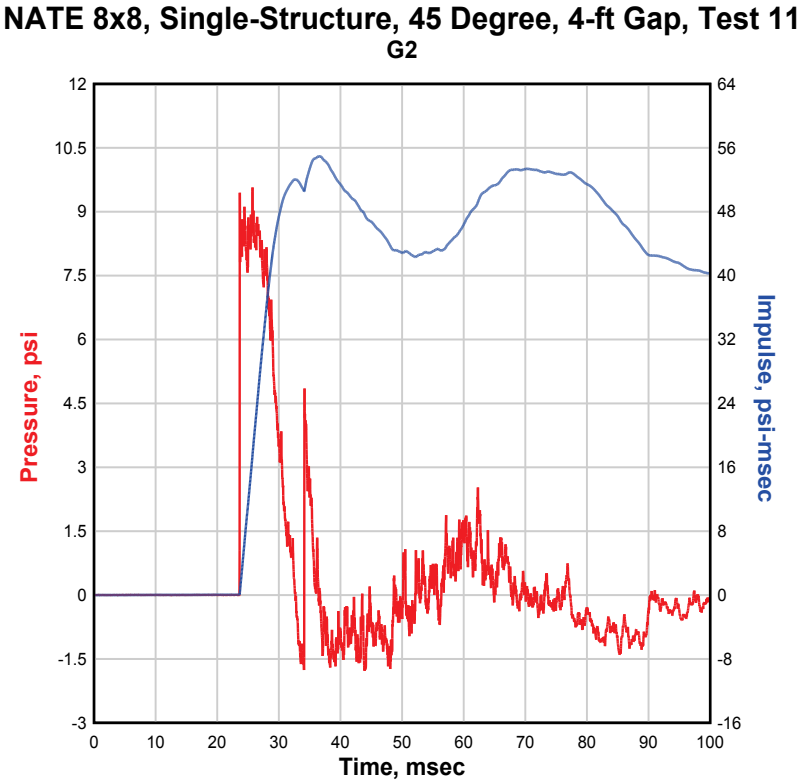

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
15
12.5
10
7.5
5
2.5
0
-2.5
-5
-7.5
-10
90
75
60
45
30
15
0
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

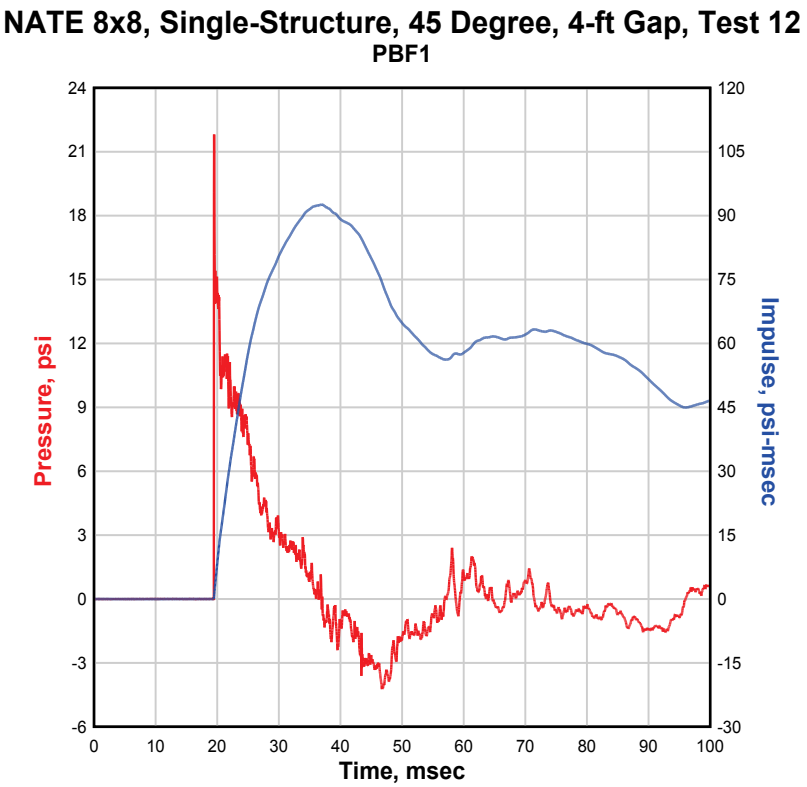

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

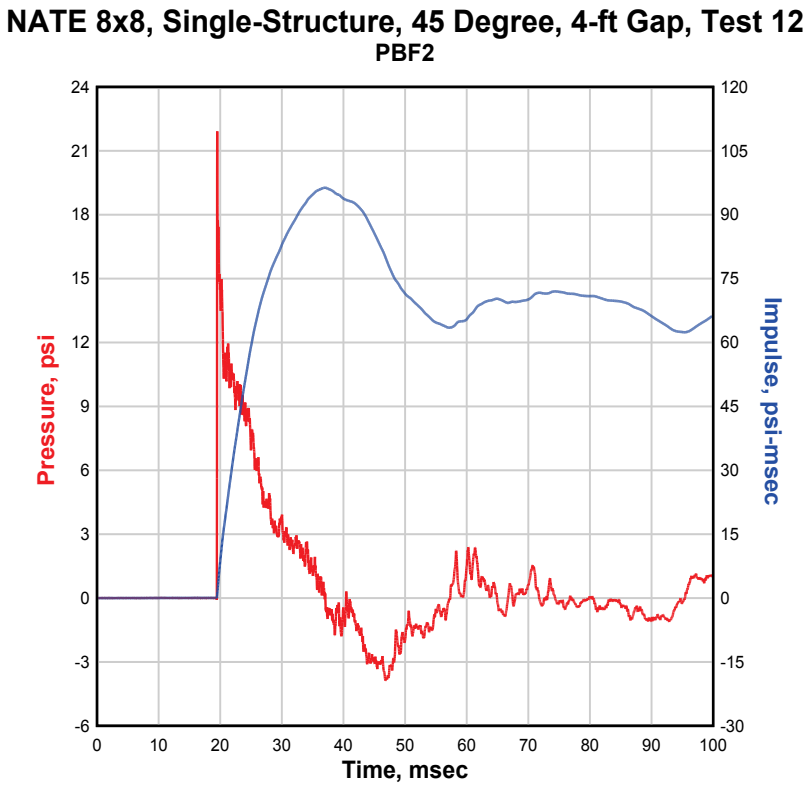

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

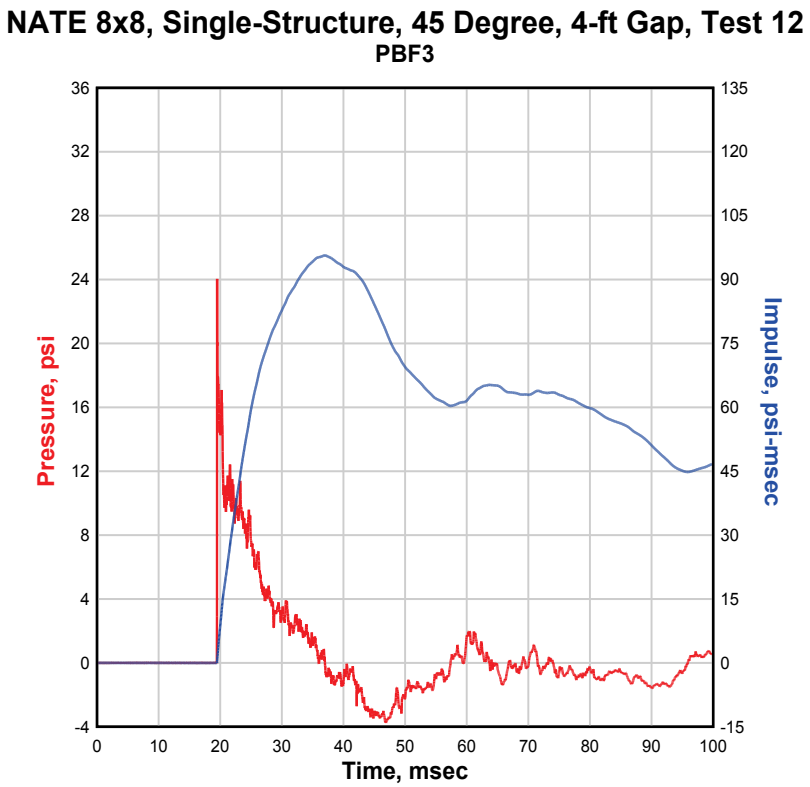

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
80
70
60
50
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100

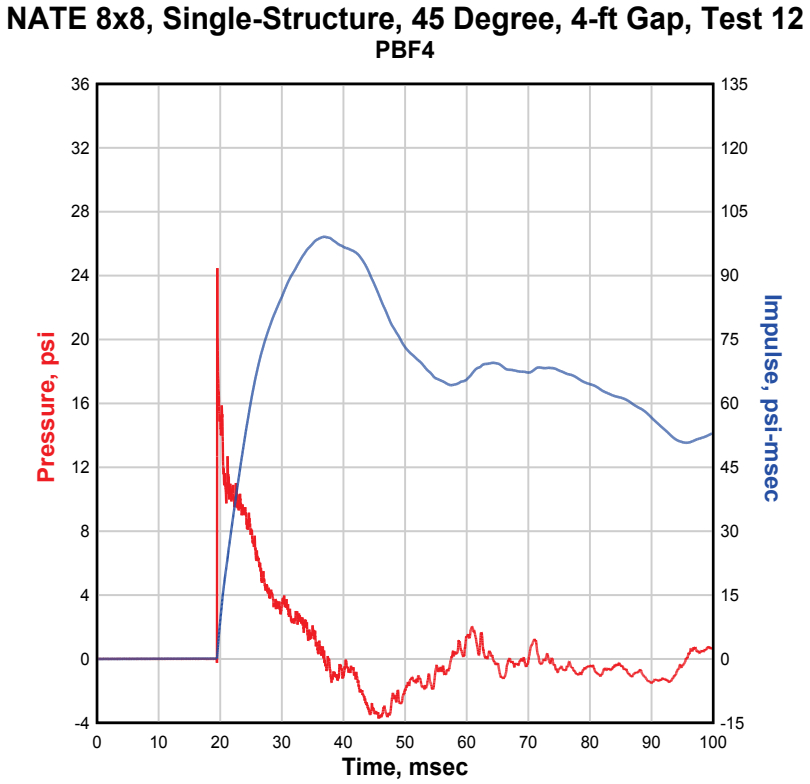

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
G1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

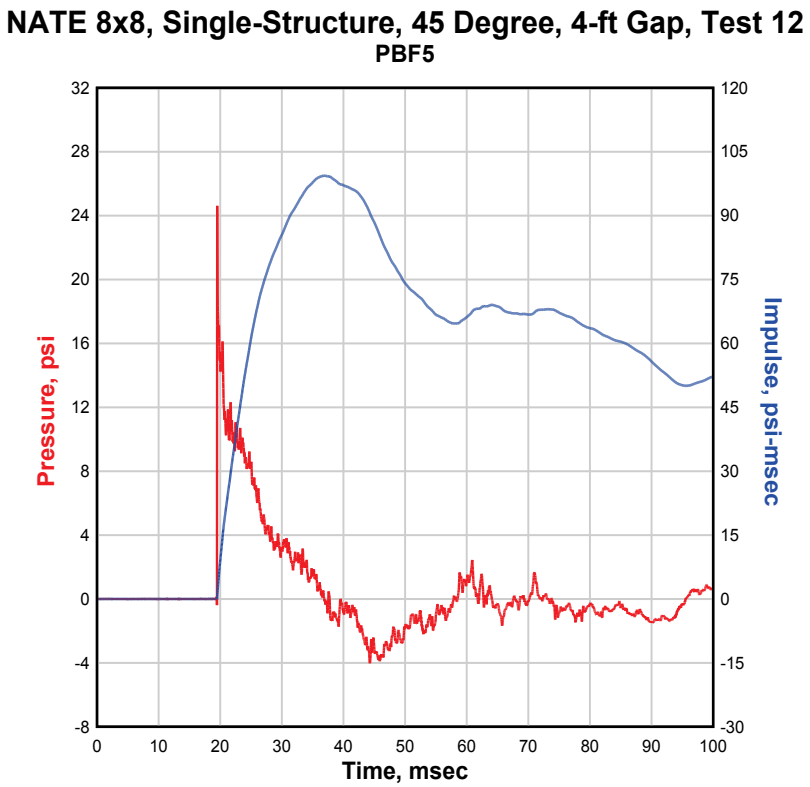

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 11
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

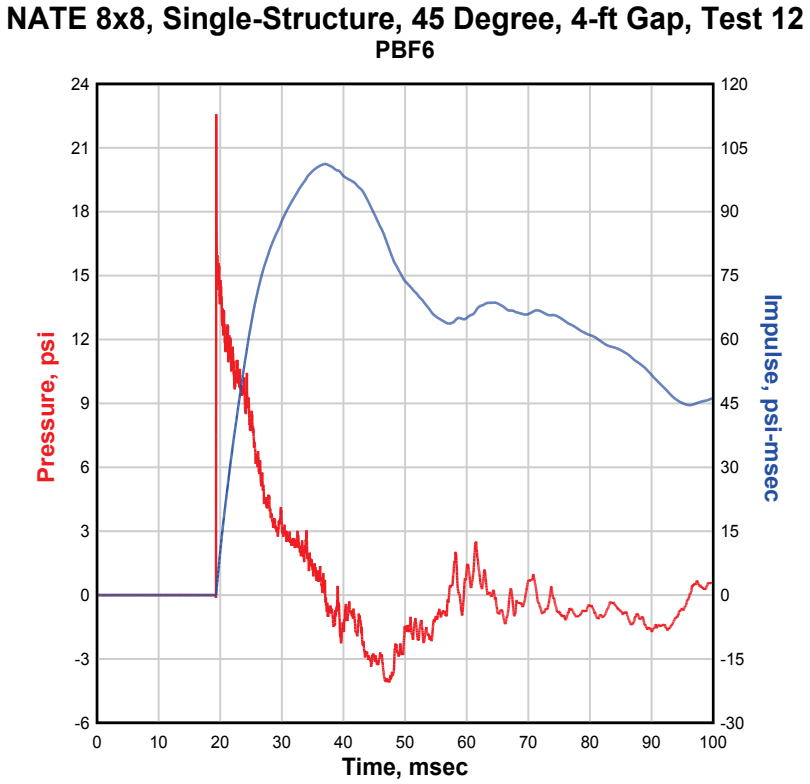

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

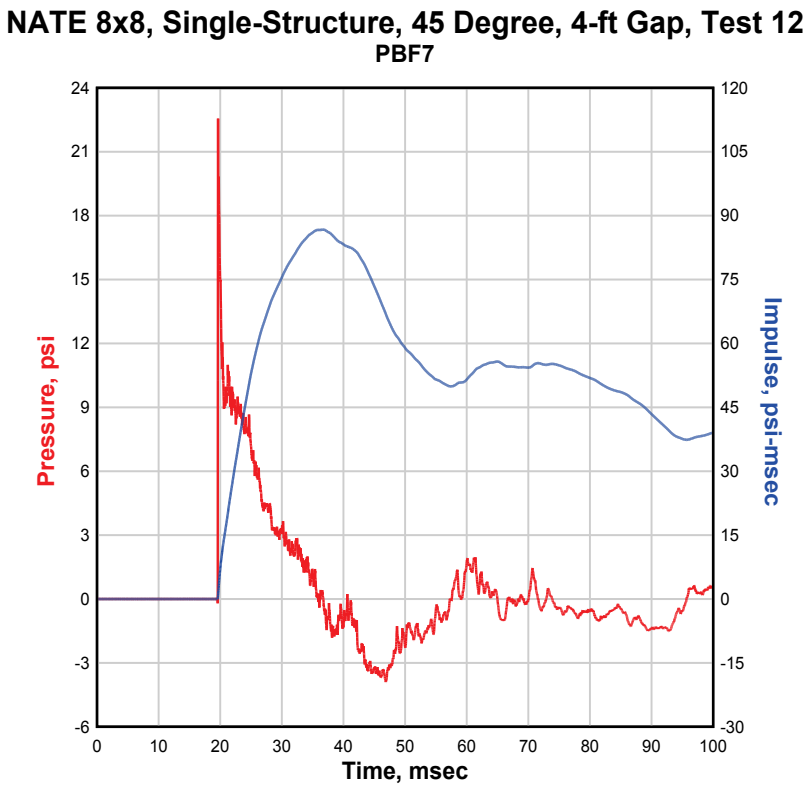

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

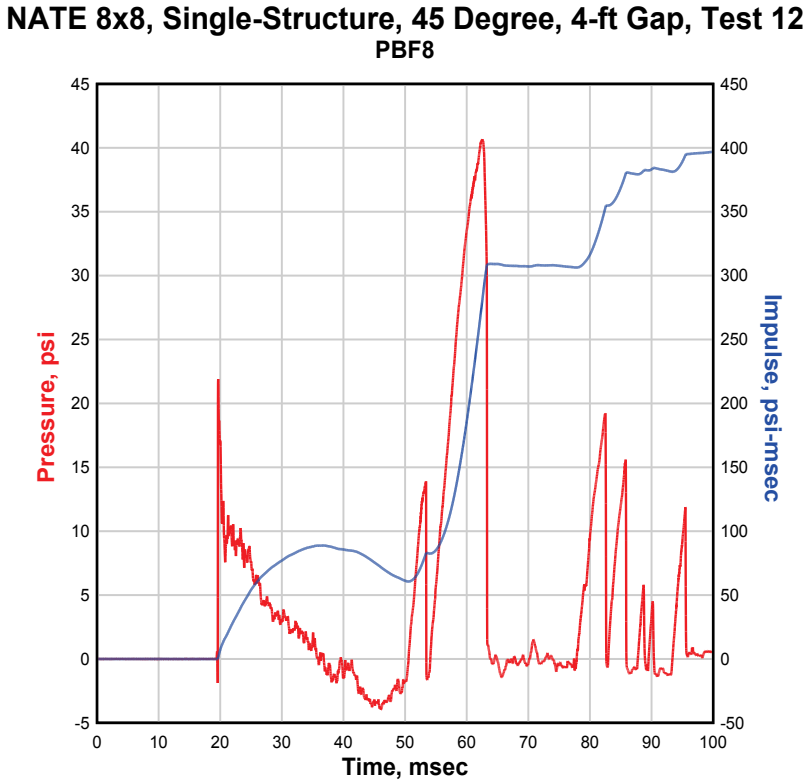

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

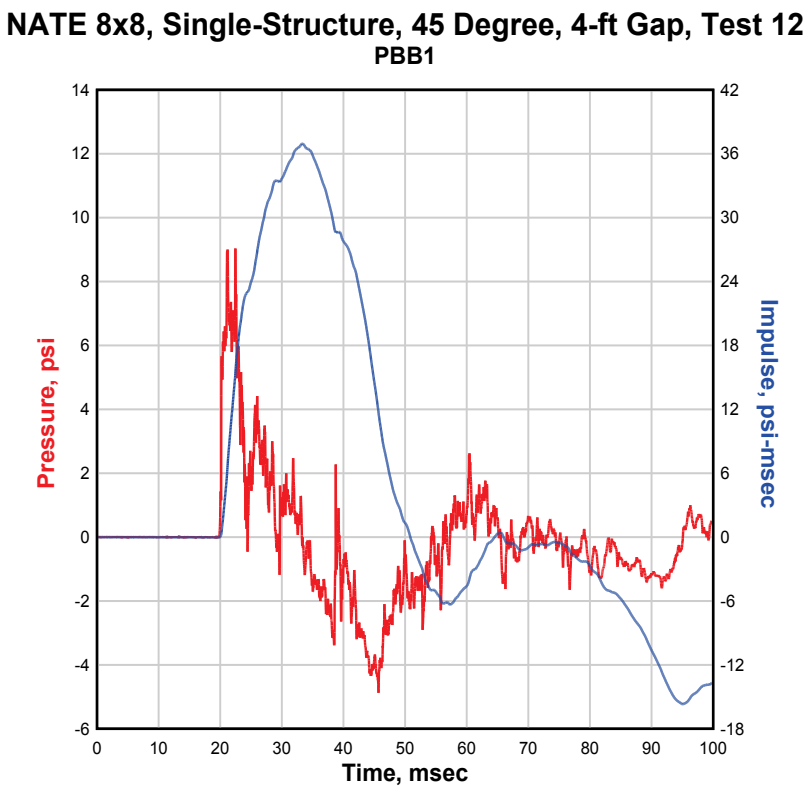

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

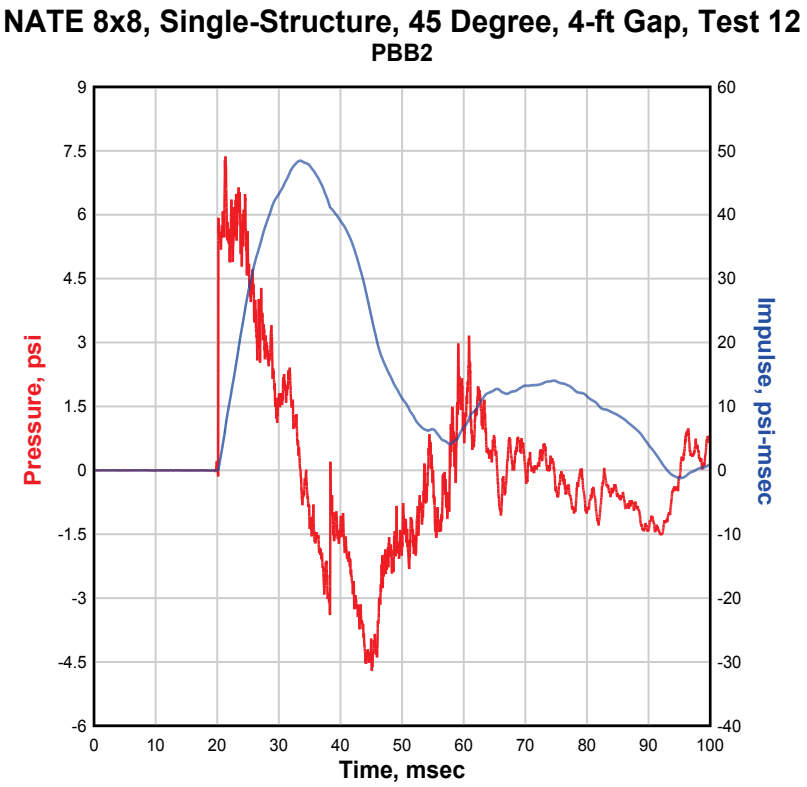

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

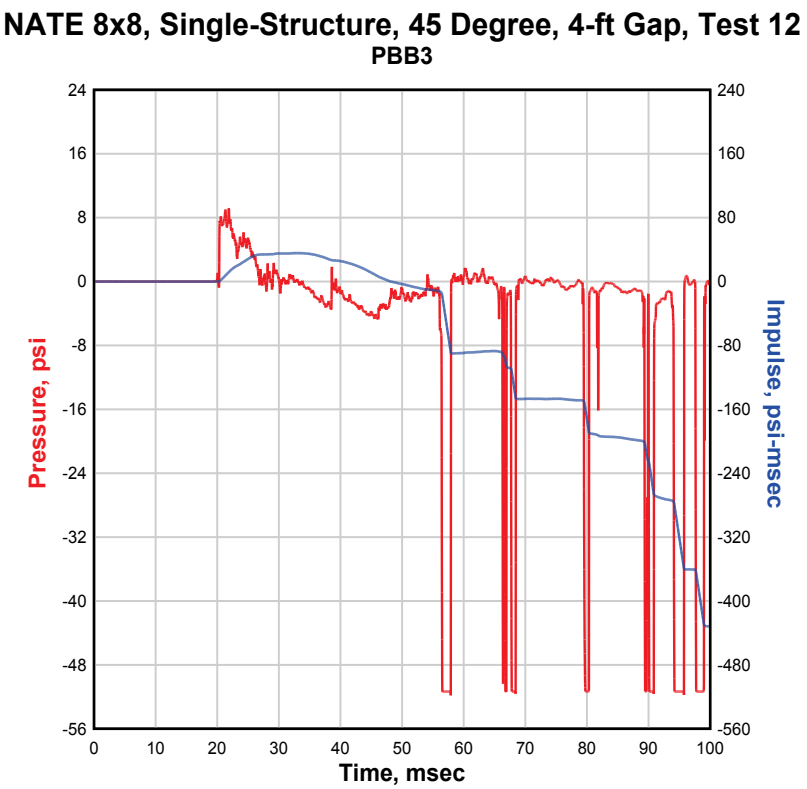

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

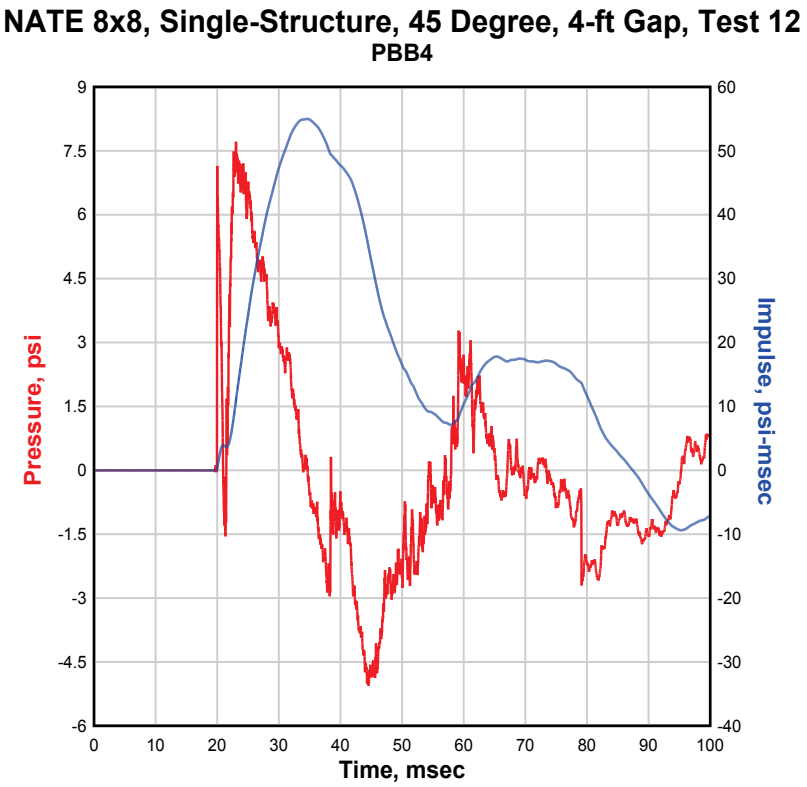

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

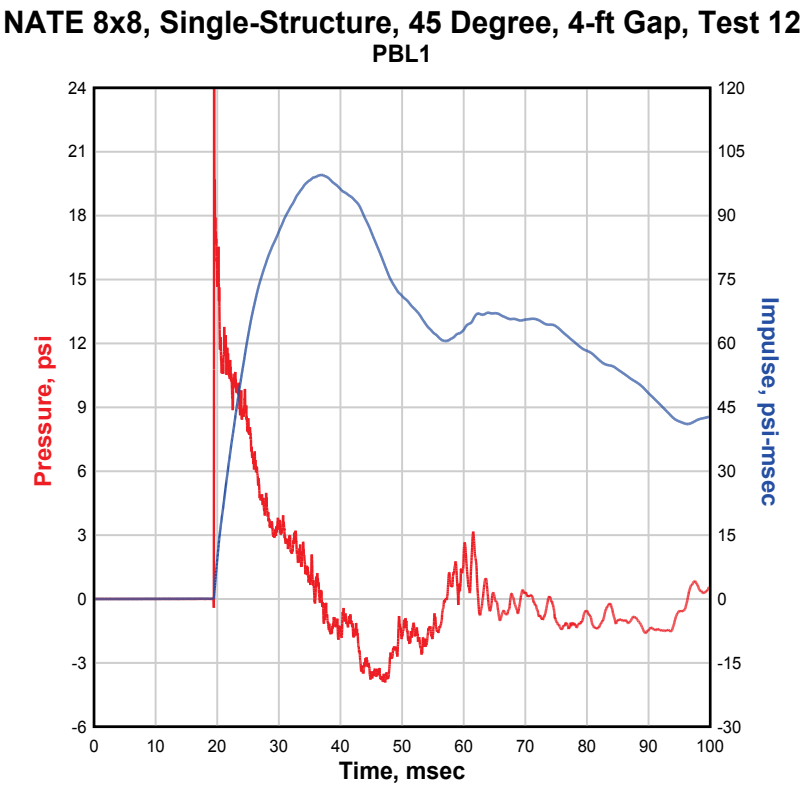

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
45
40
35
30
25
20
15
10
5
0
-5
450
400
350
300
250
200
150
100
50
0
-50
0
10
20
30
40
50
60
70
80
90
100

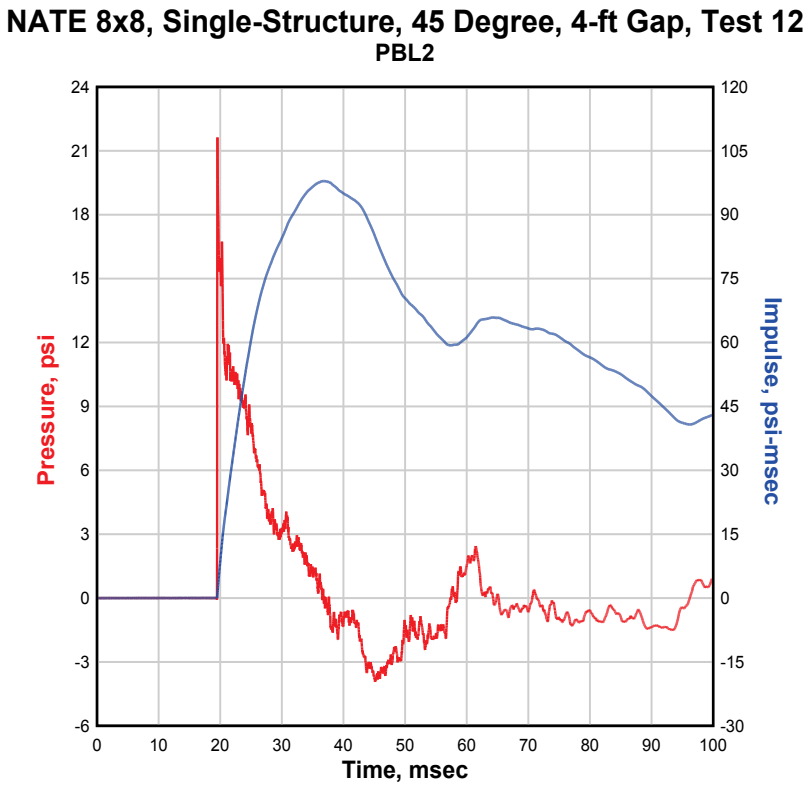

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
42
36
30
24
18
12
6
0
-6
-12
-18
0
10
20
30
40
50
60
70
80
90
100

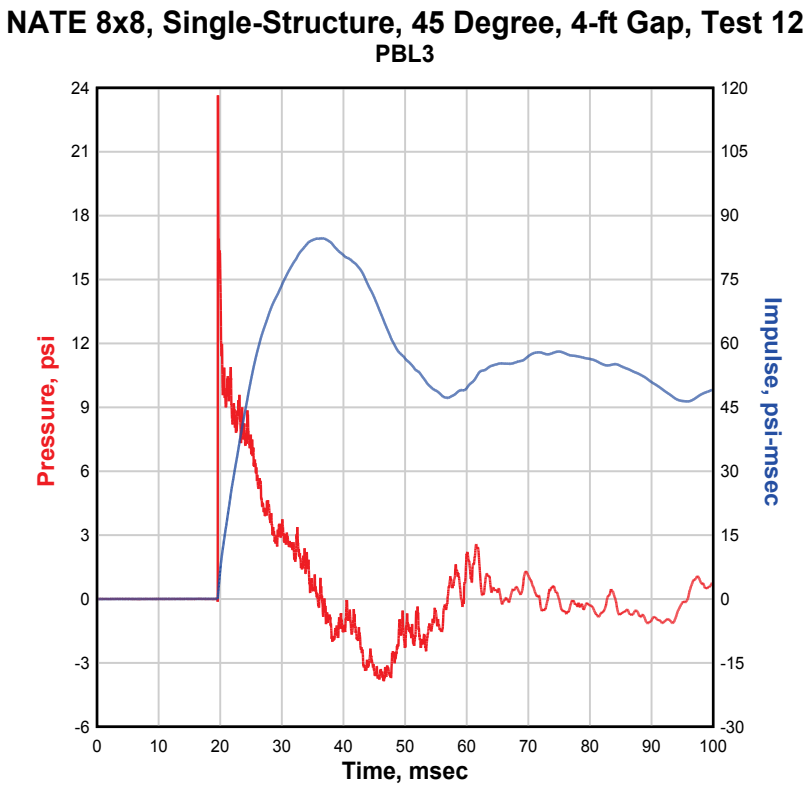

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100

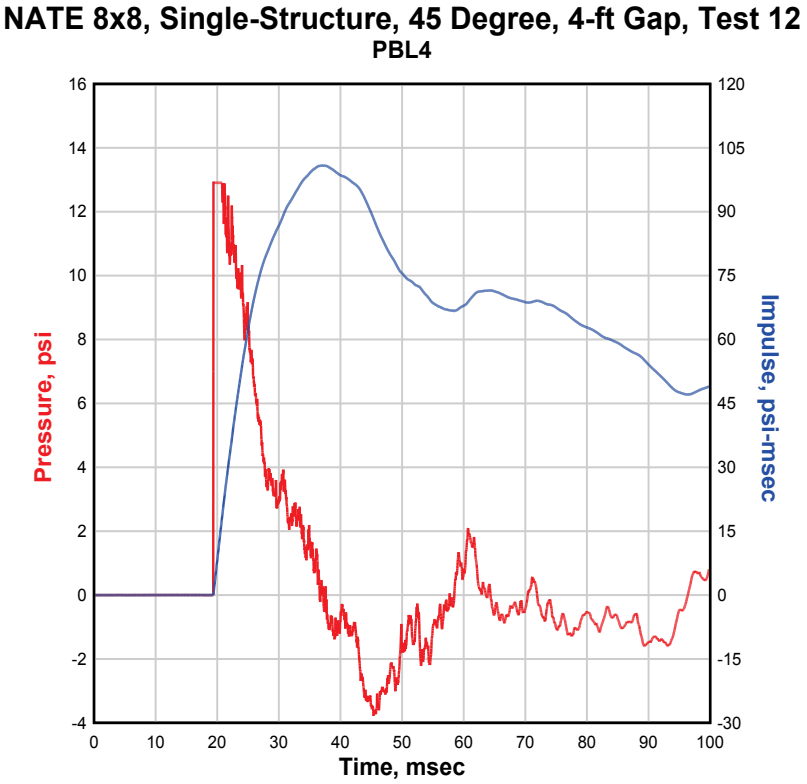

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
240
160
80
0
-80
-160
-240
-320
-400
-480
-560
0
10
20
30
40
50
60
70
80
90
100

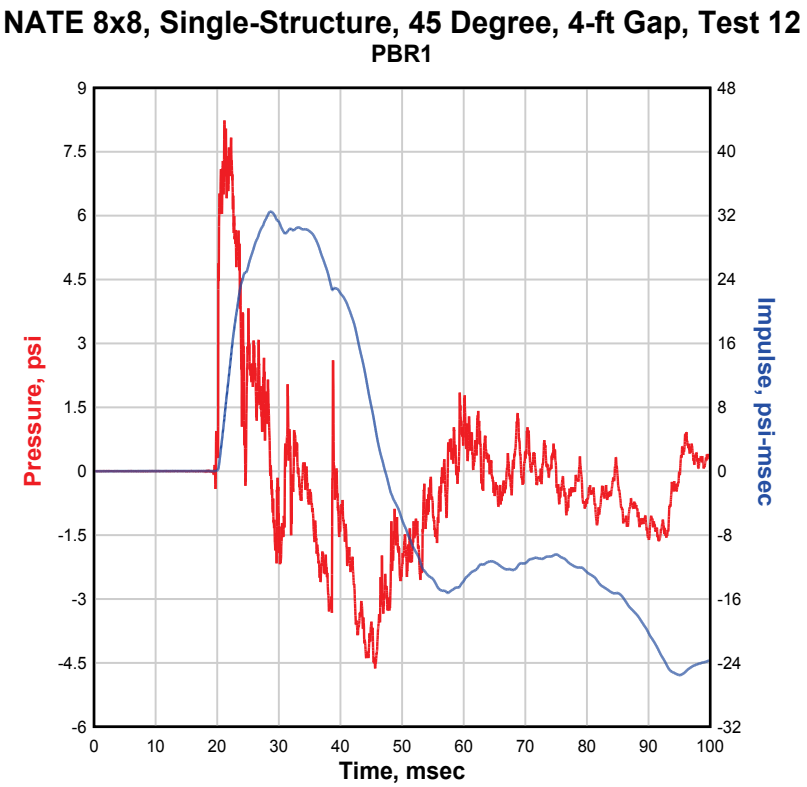

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100

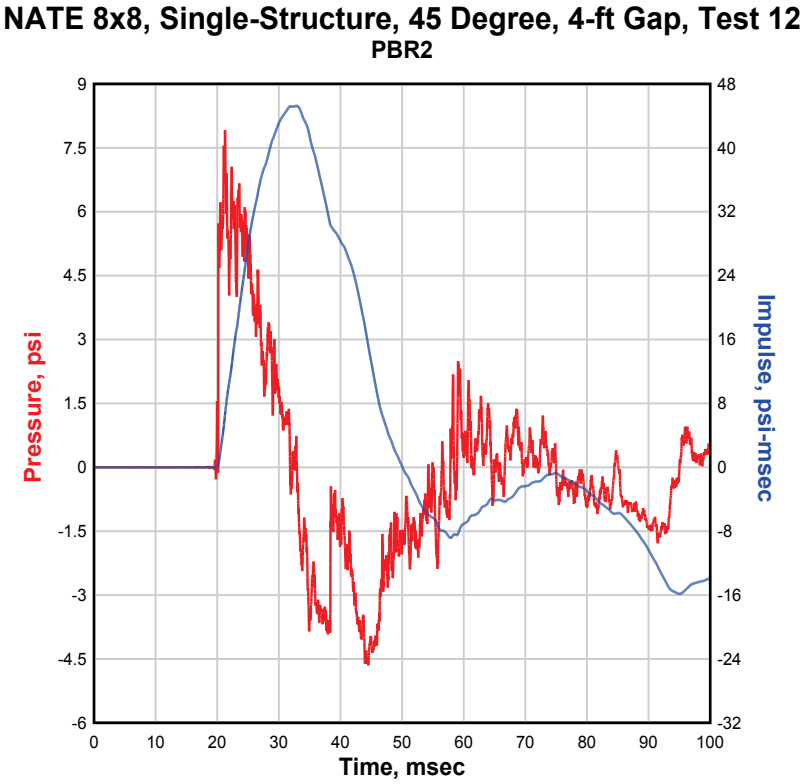

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

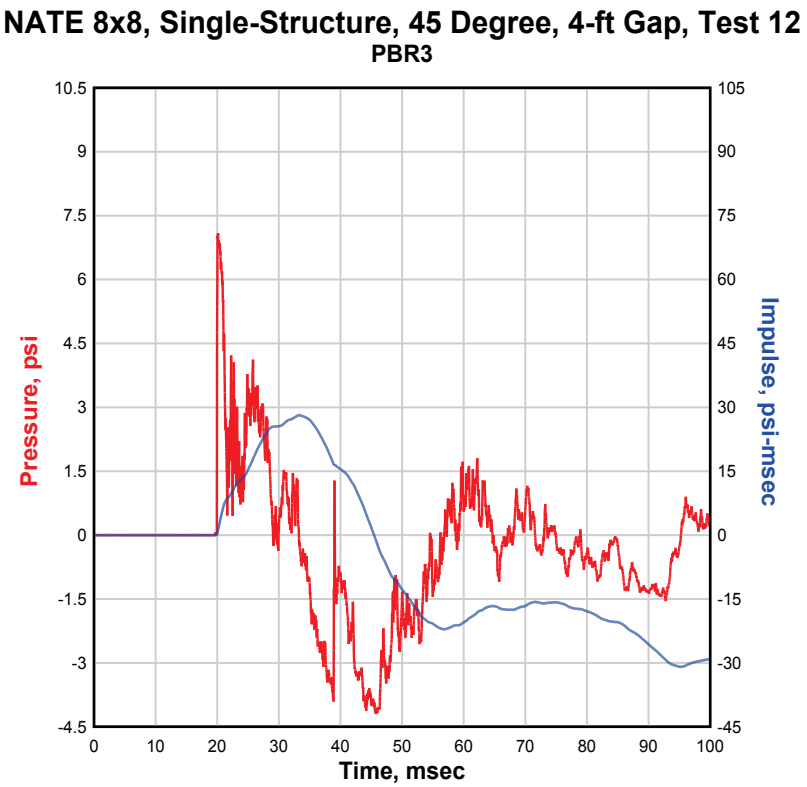

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

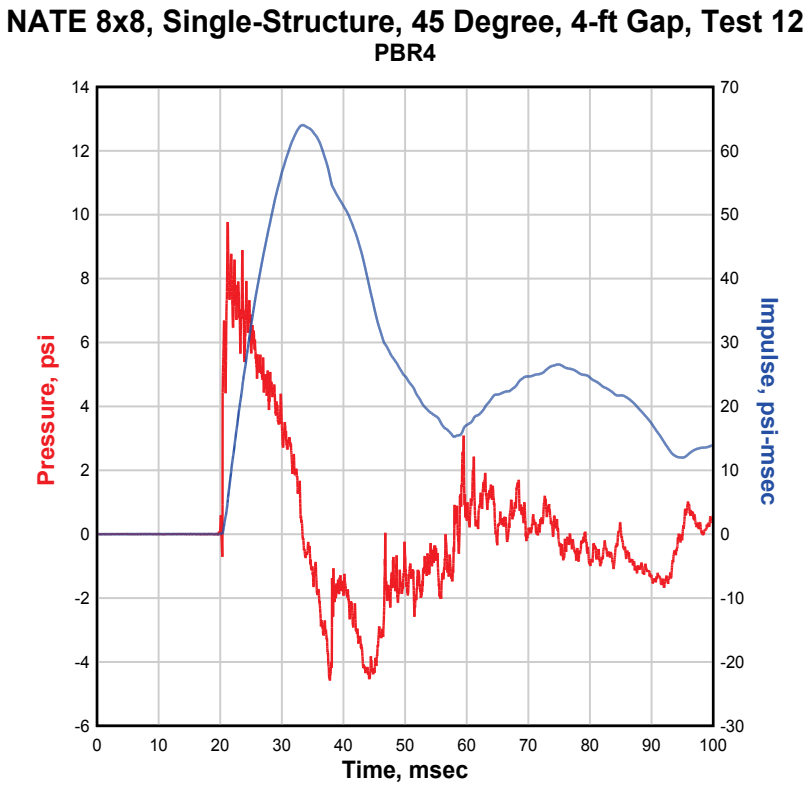

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

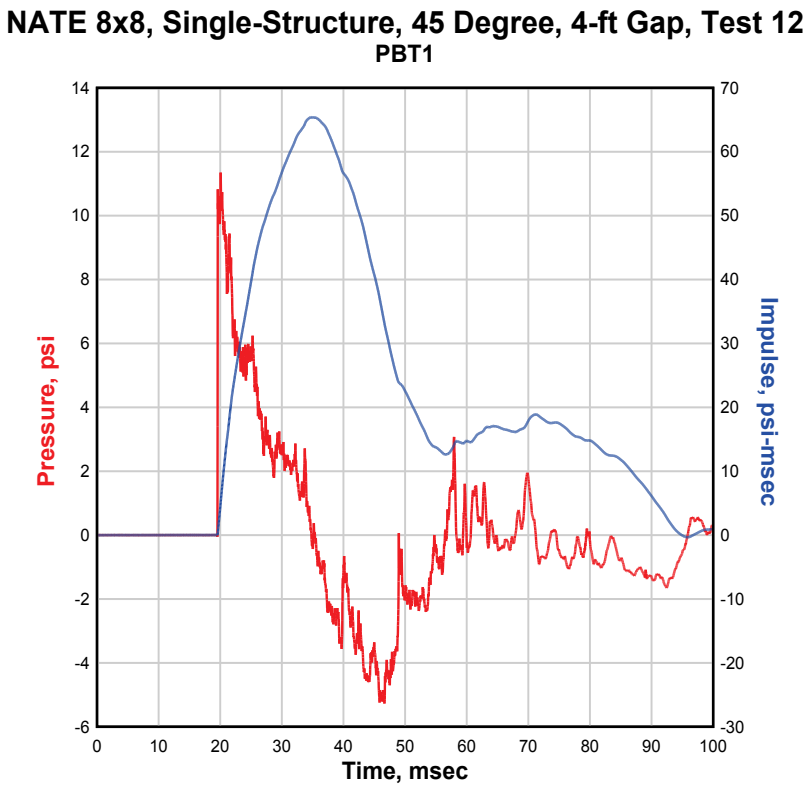

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

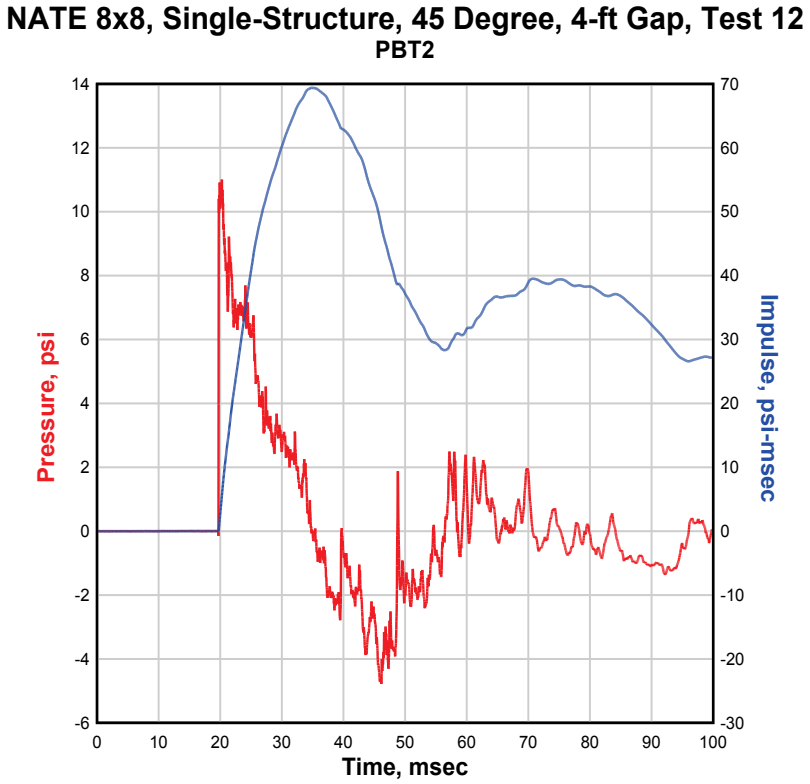

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100

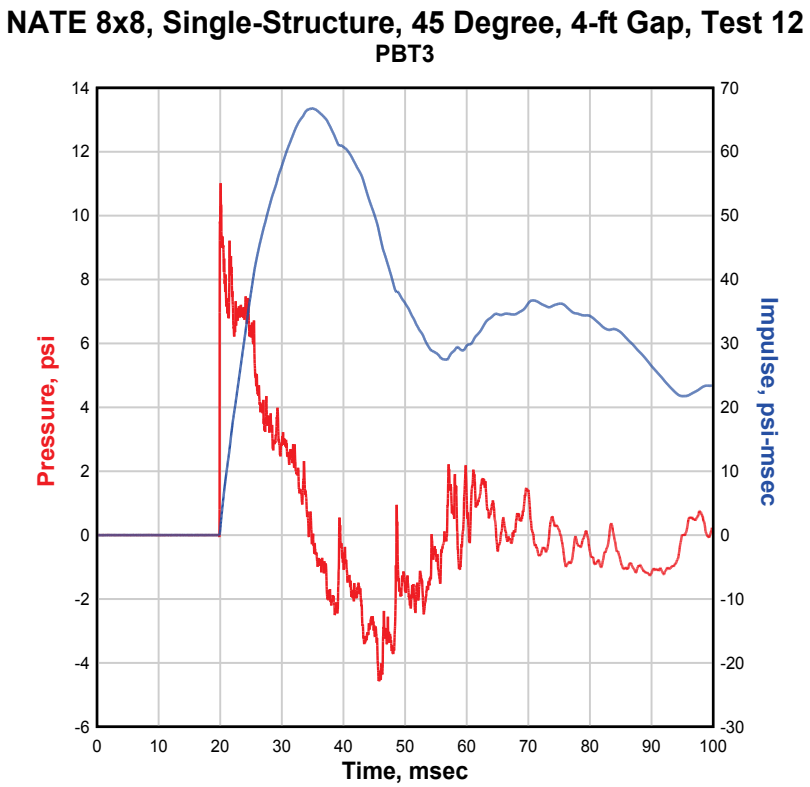

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100

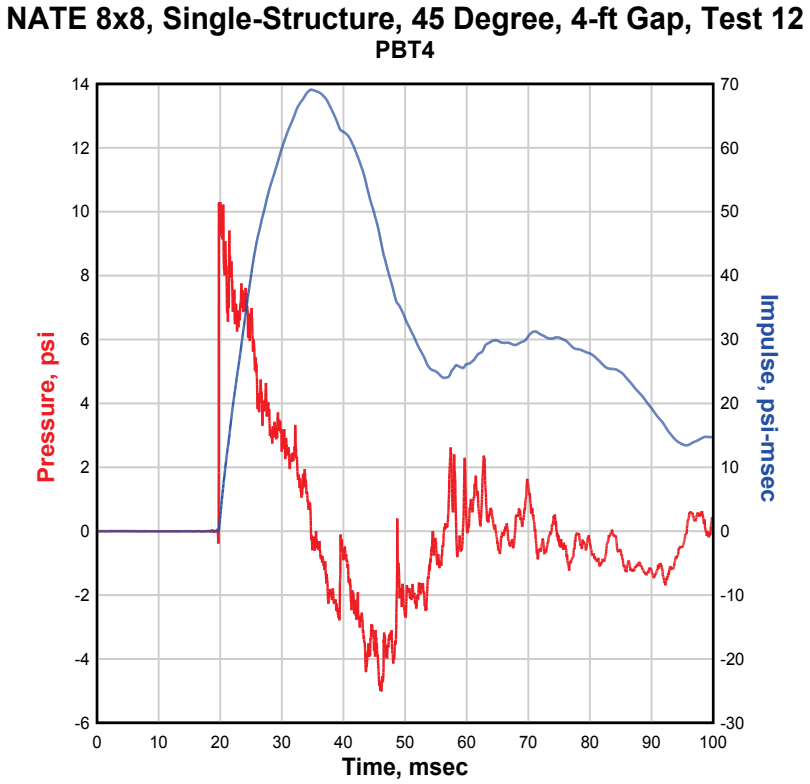

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

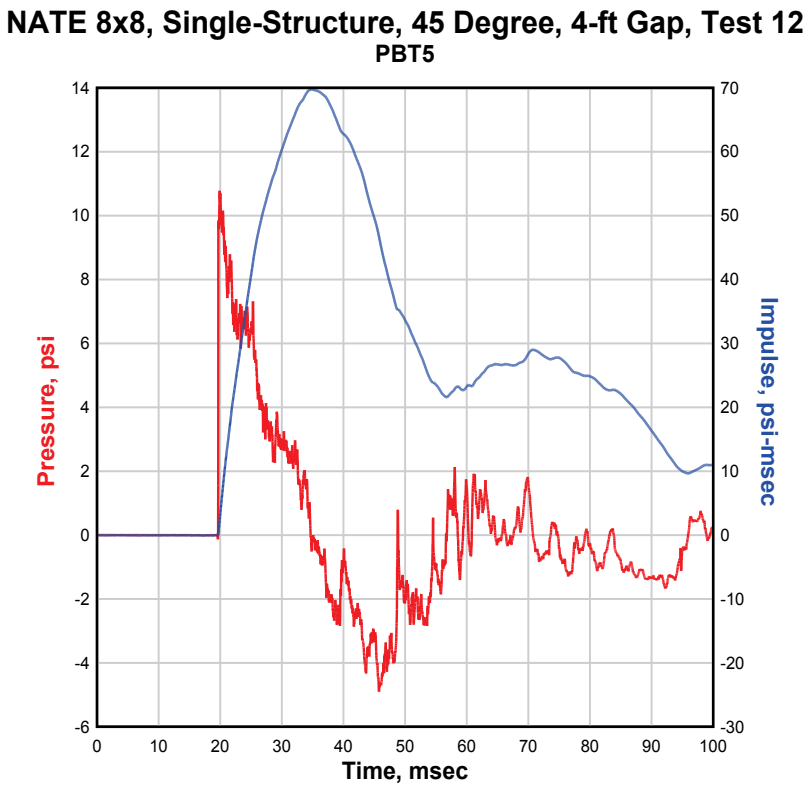

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

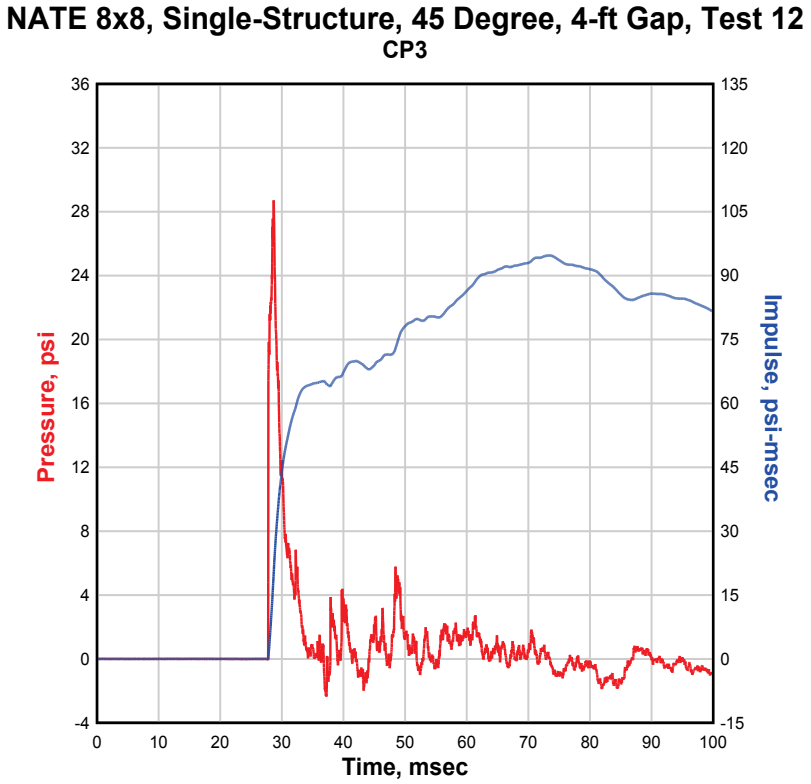

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

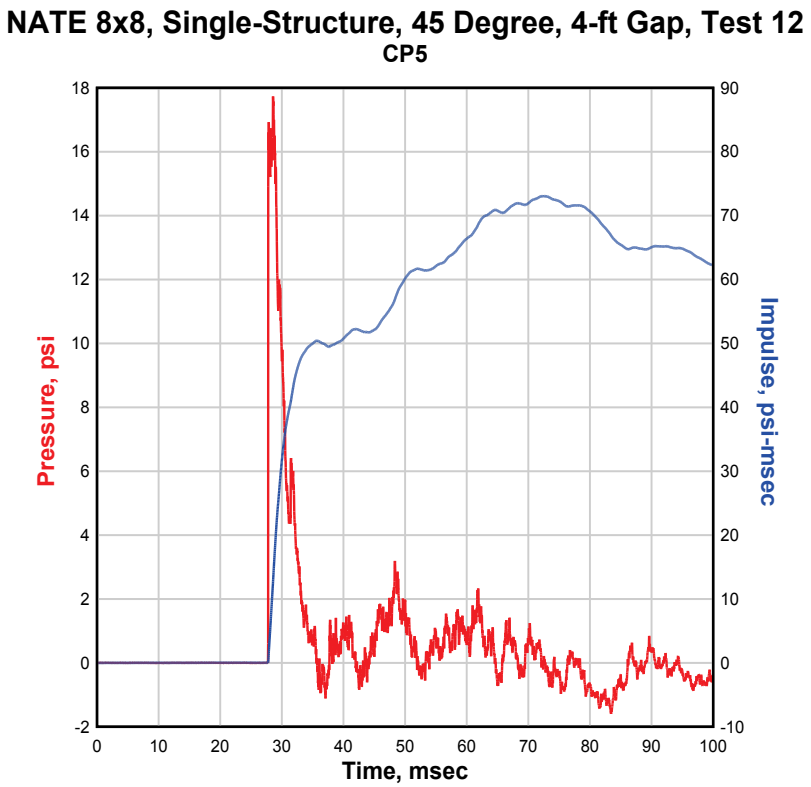

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

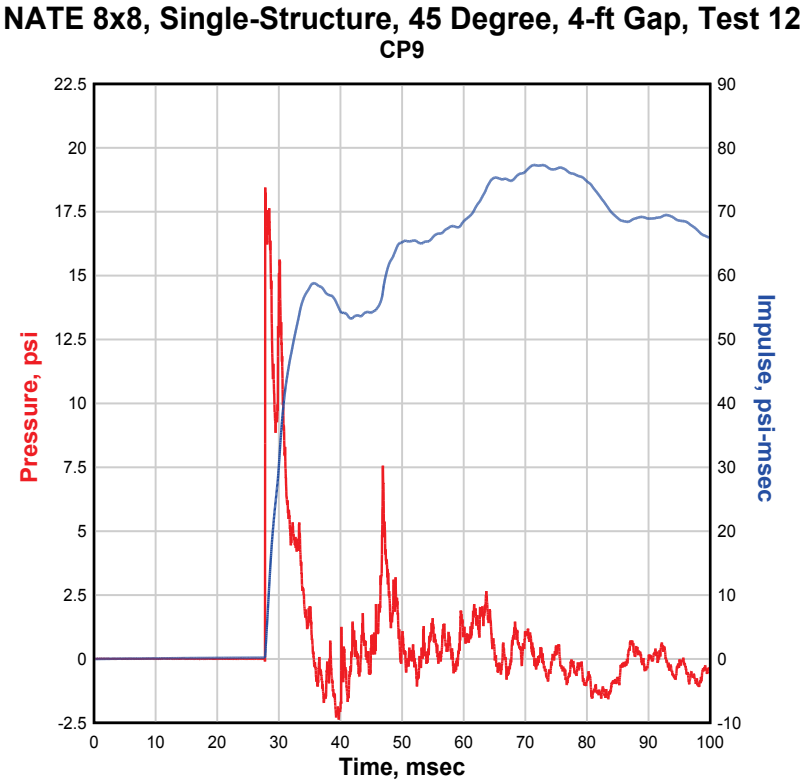

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

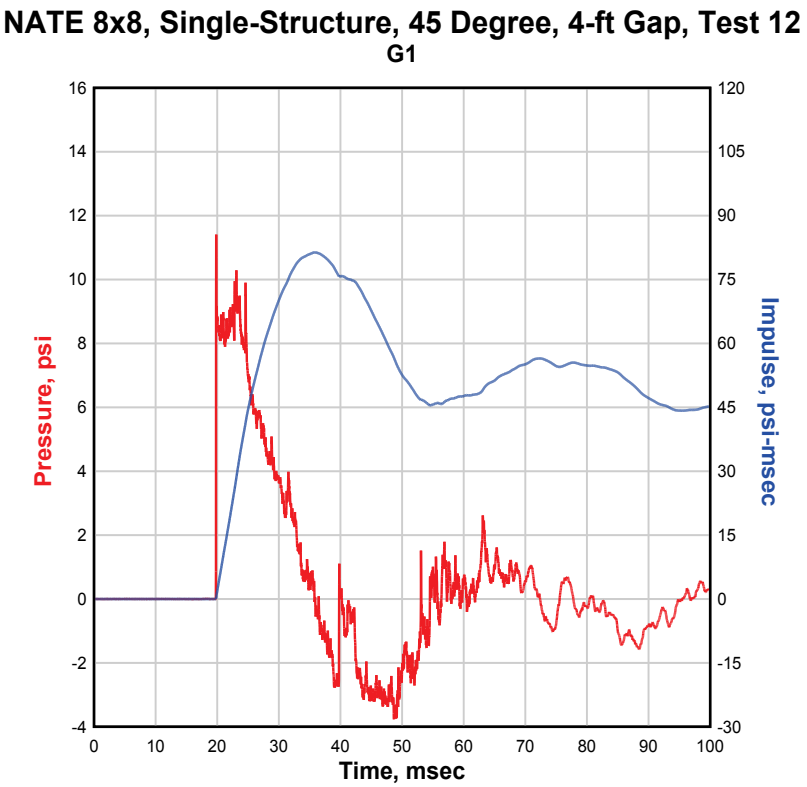

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

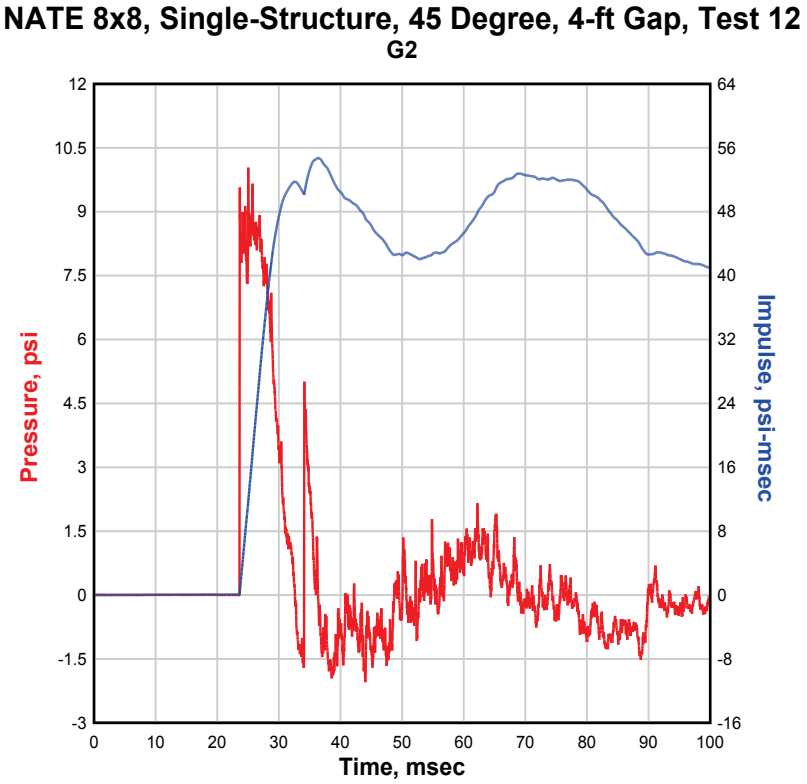

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

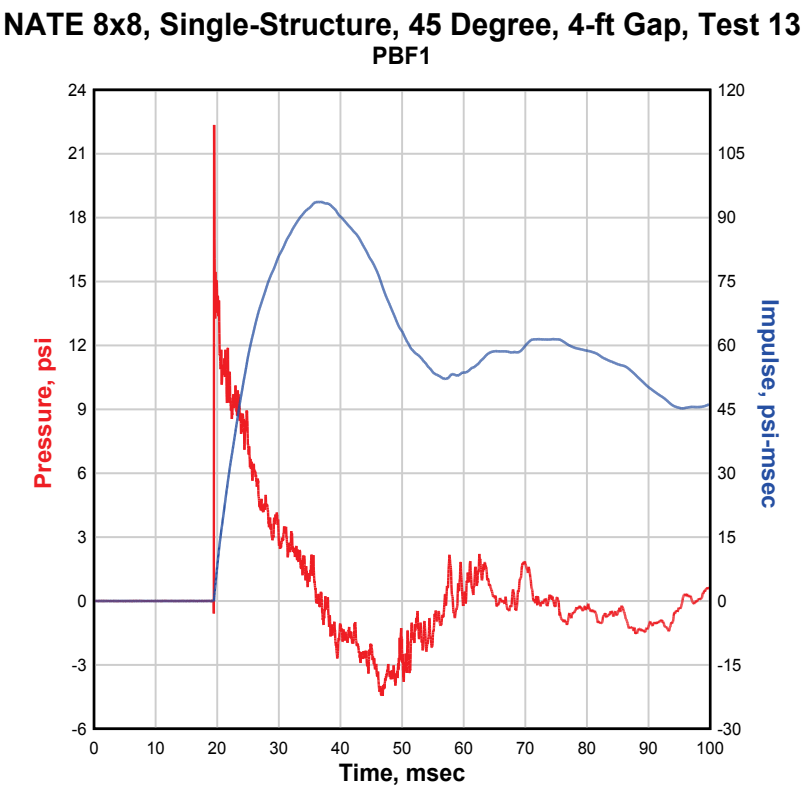

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

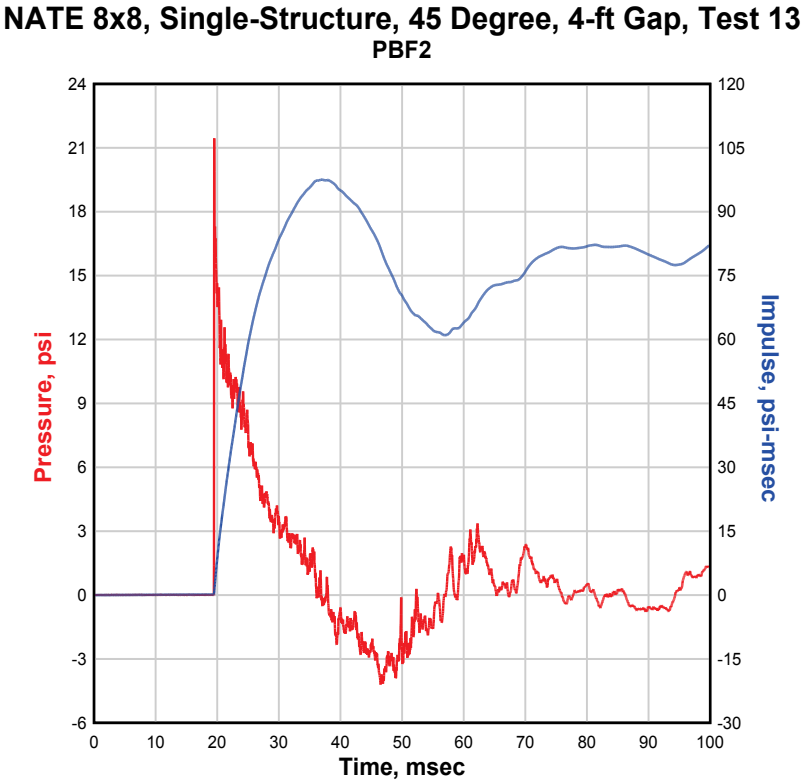

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
18
16
14
12
10
8
6
4
2
0
-2
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

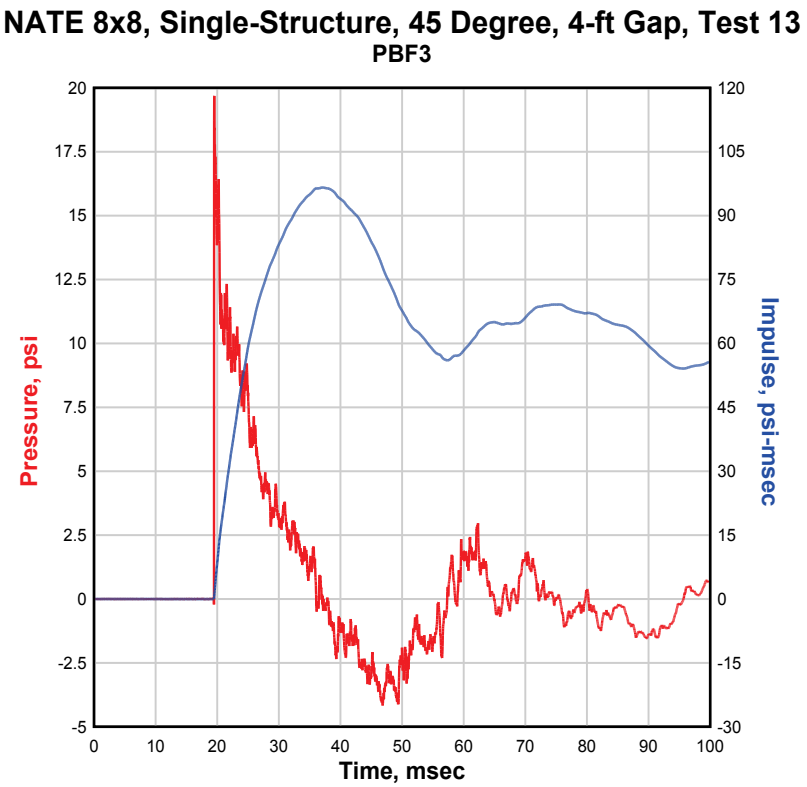

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

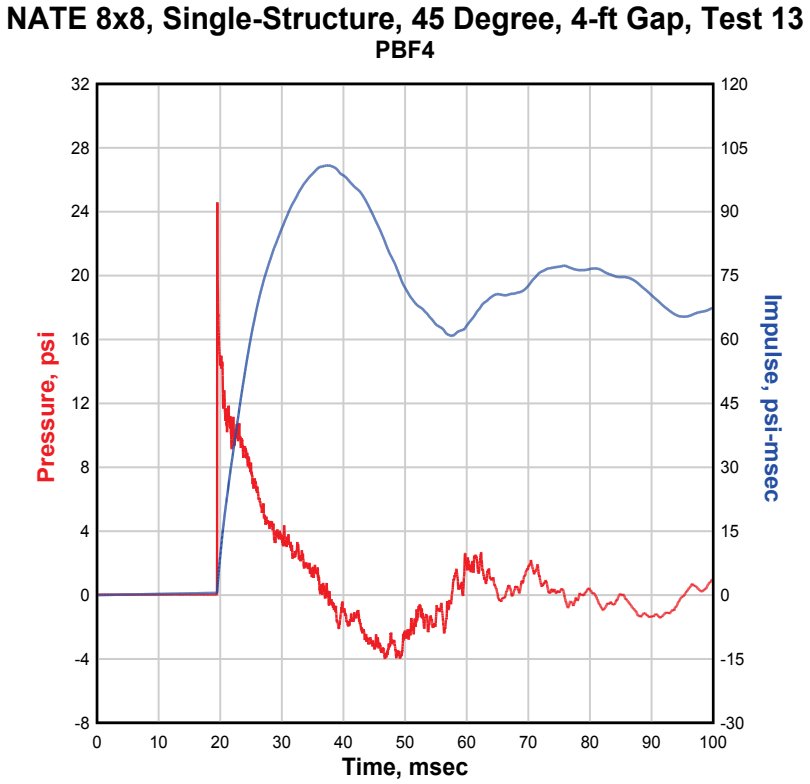

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
G1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

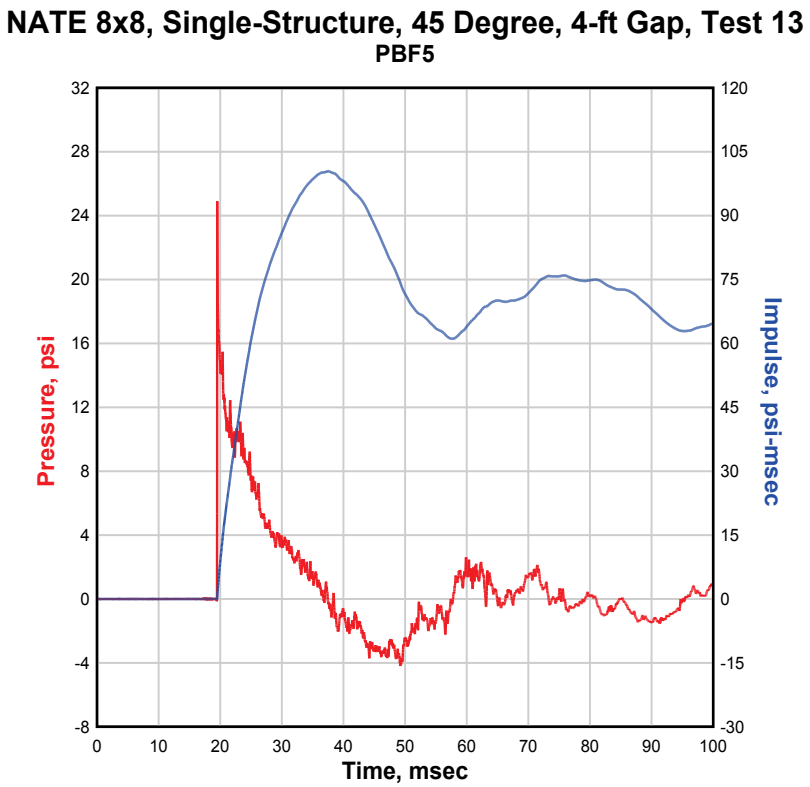

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 12
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

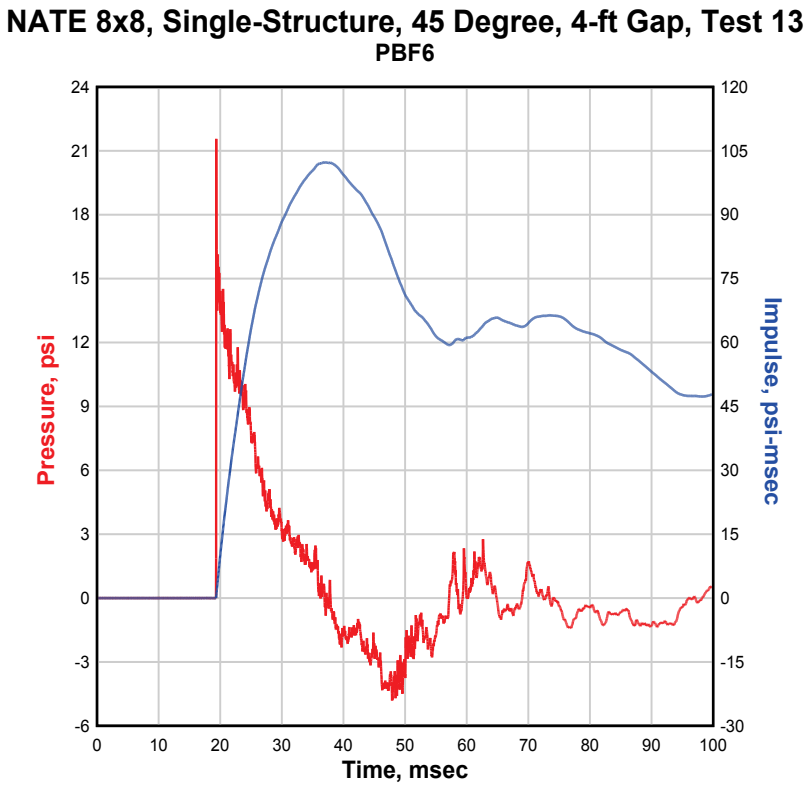

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

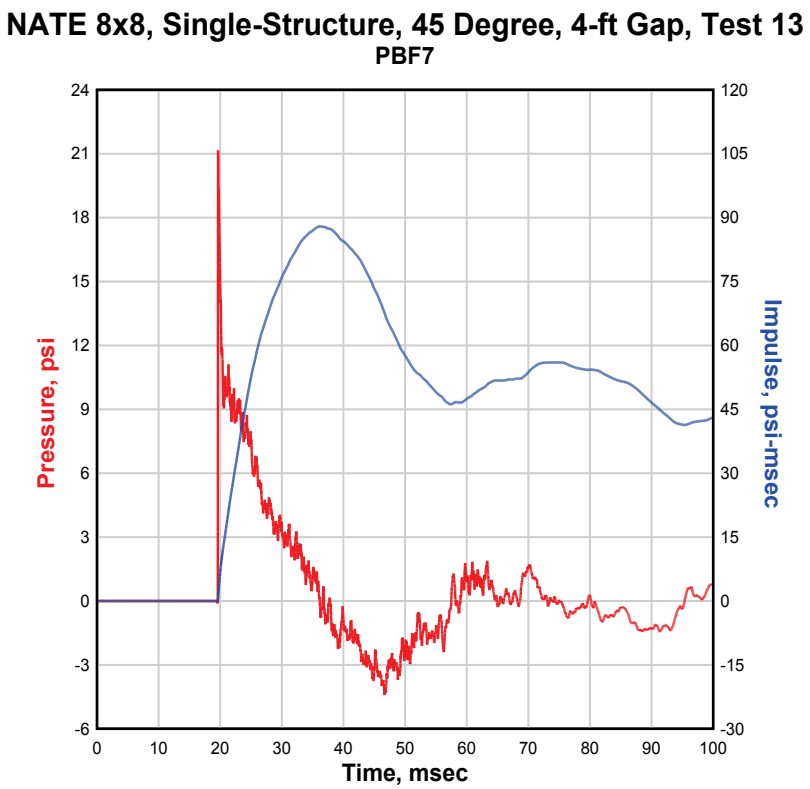

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

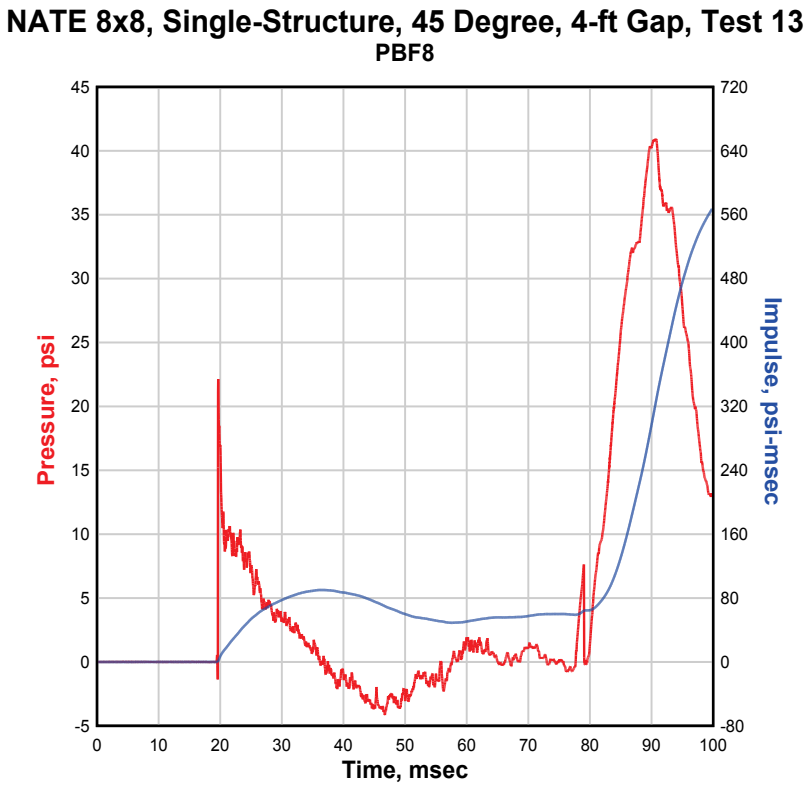

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

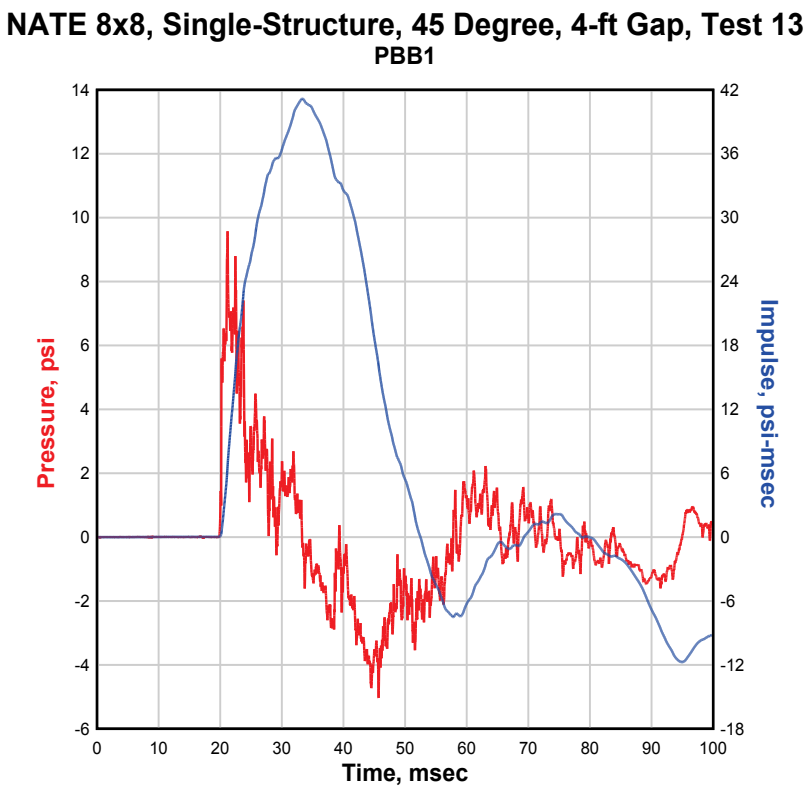

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

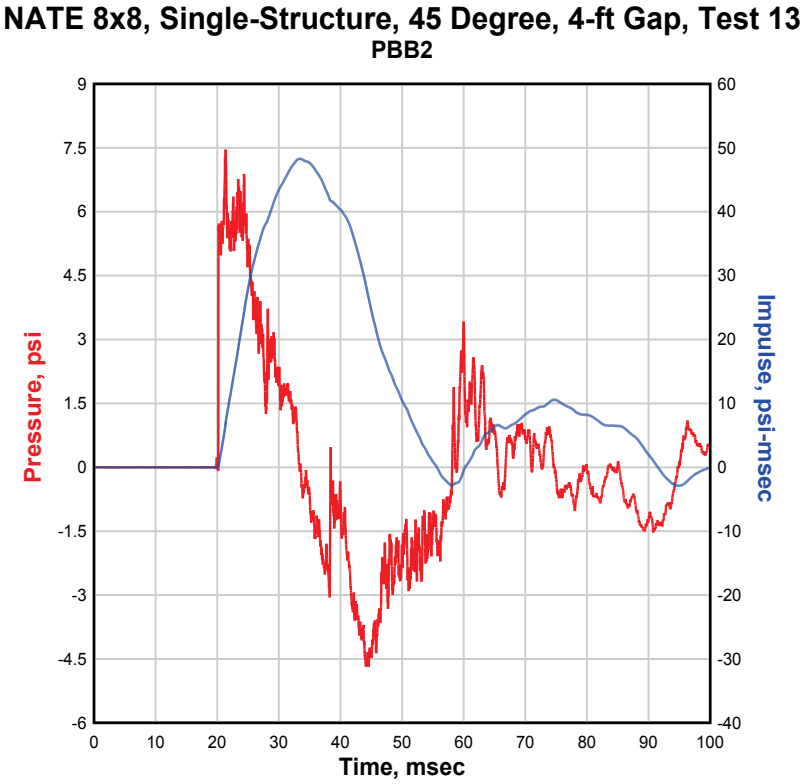

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

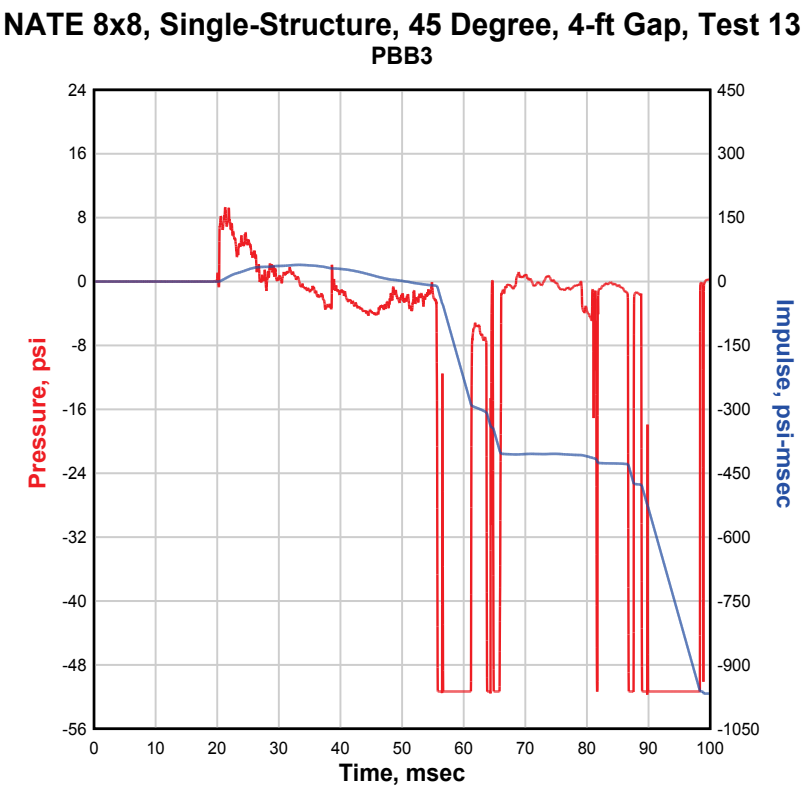

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

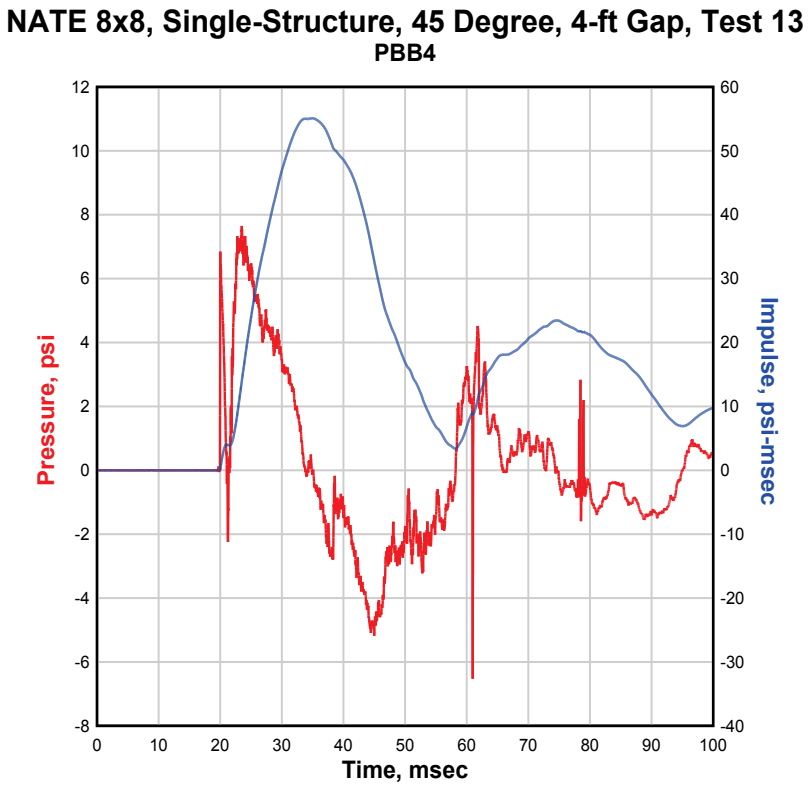

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

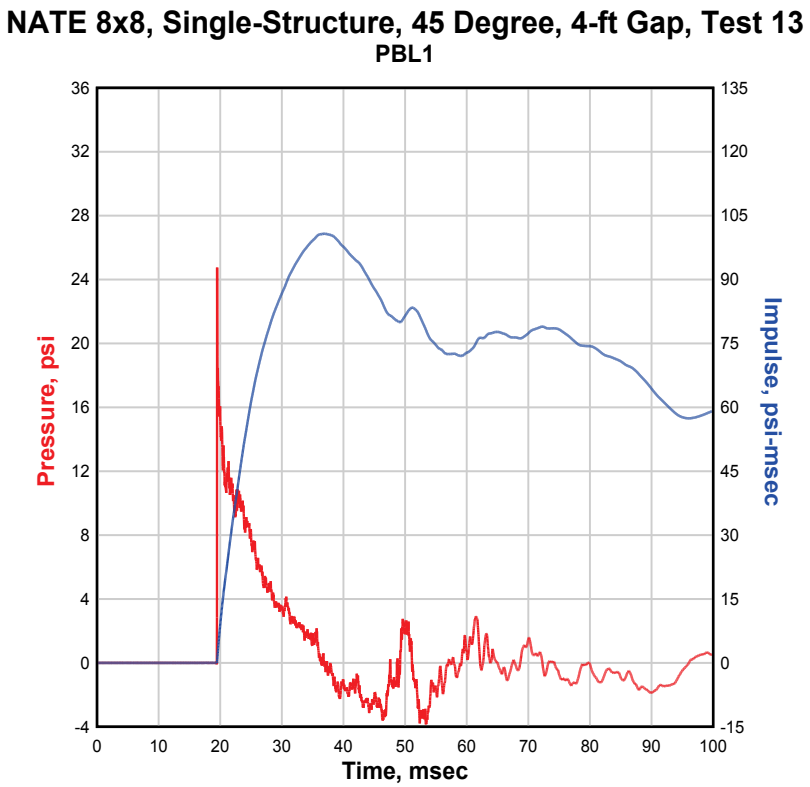

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
45
40
35
30
25
20
15
10
5
0
-5
720
640
560
480
400
320
240
160
80
0
-80
0
10
20
30
40
50
60
70
80
90
100

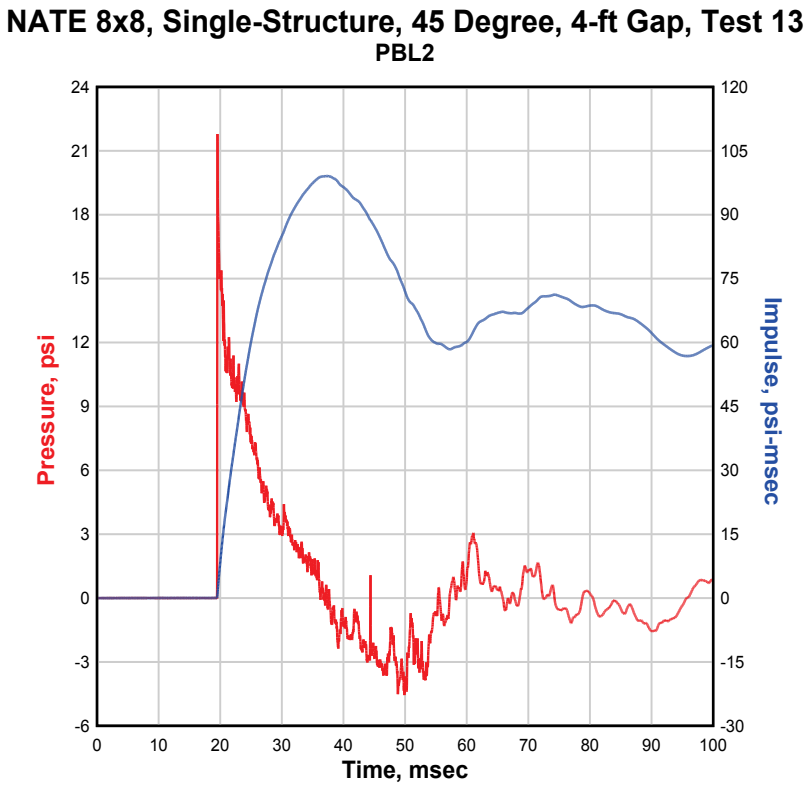

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
42
36
30
24
18
12
6
0
-6
-12
-18
0
10
20
30
40
50
60
70
80
90
100

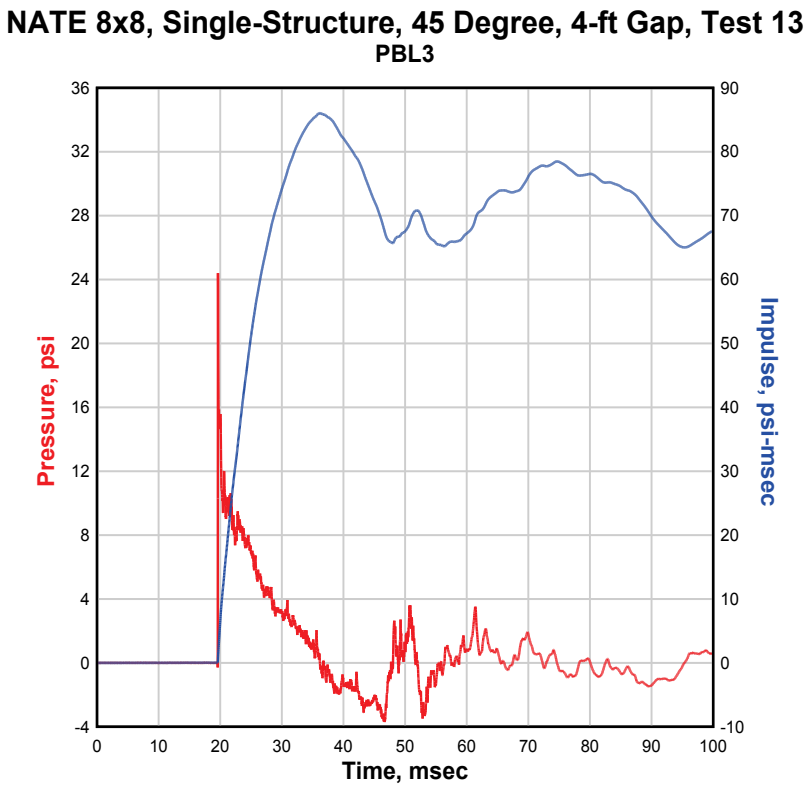

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
450
300
150
0
-150
-300
-450
-600
-750
-900
-1050
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
90
80
70
60
50
40
30
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10
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-10
0
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30
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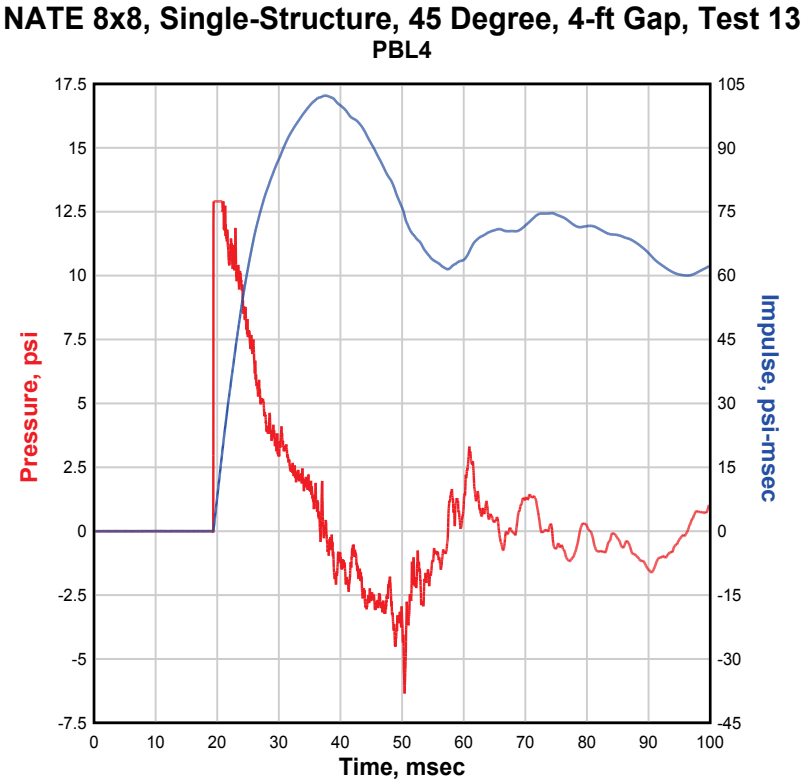
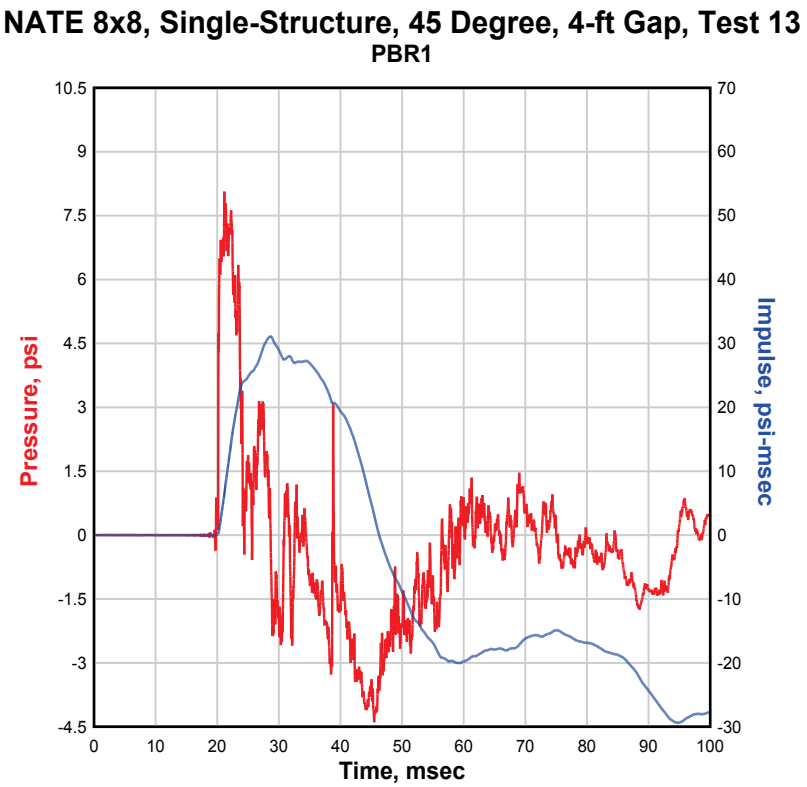
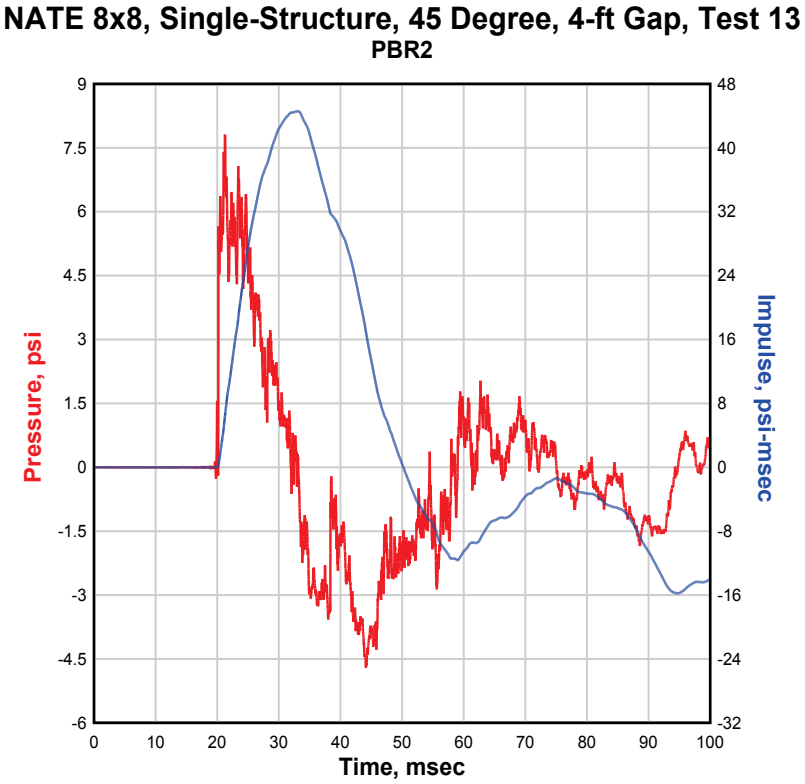
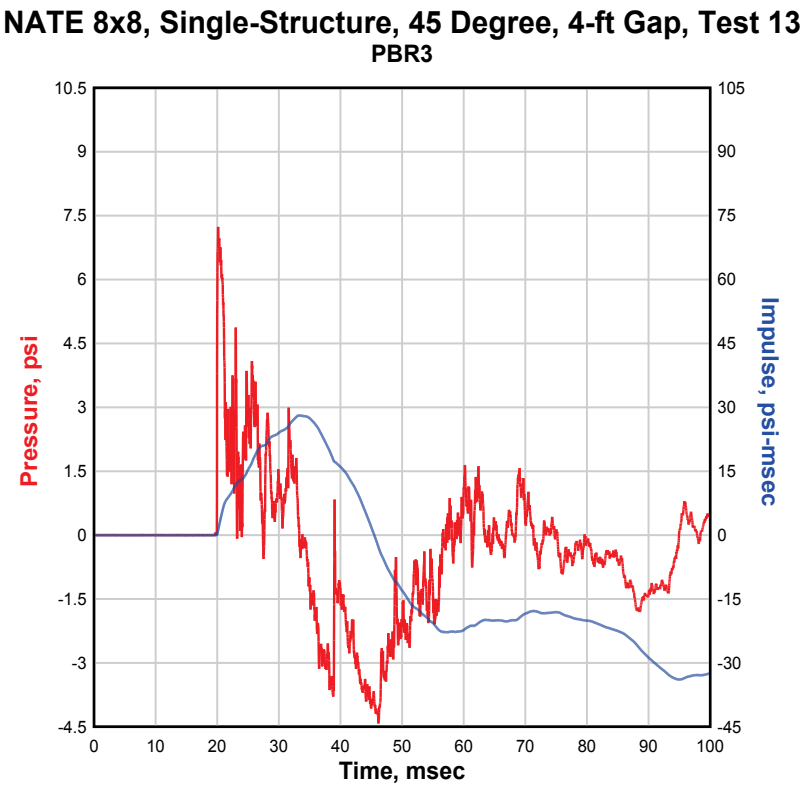
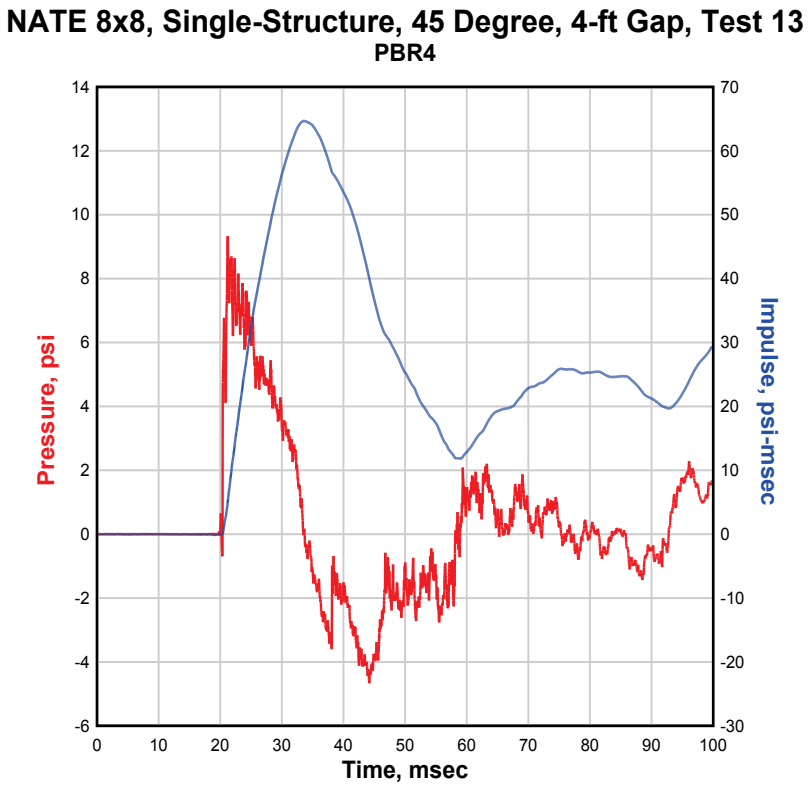
50
60
70
80
90
100

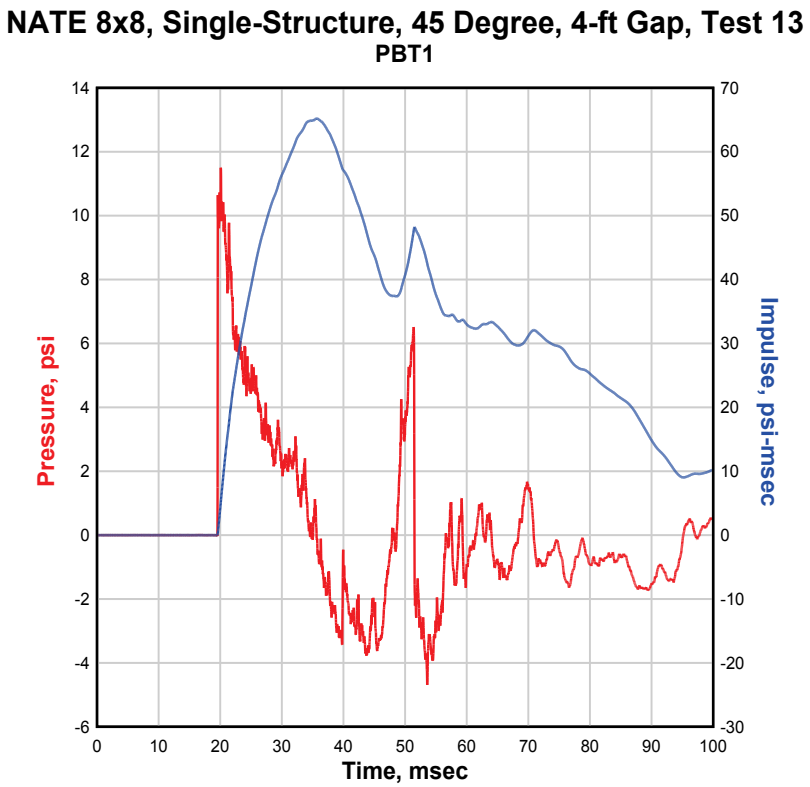

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
-7.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

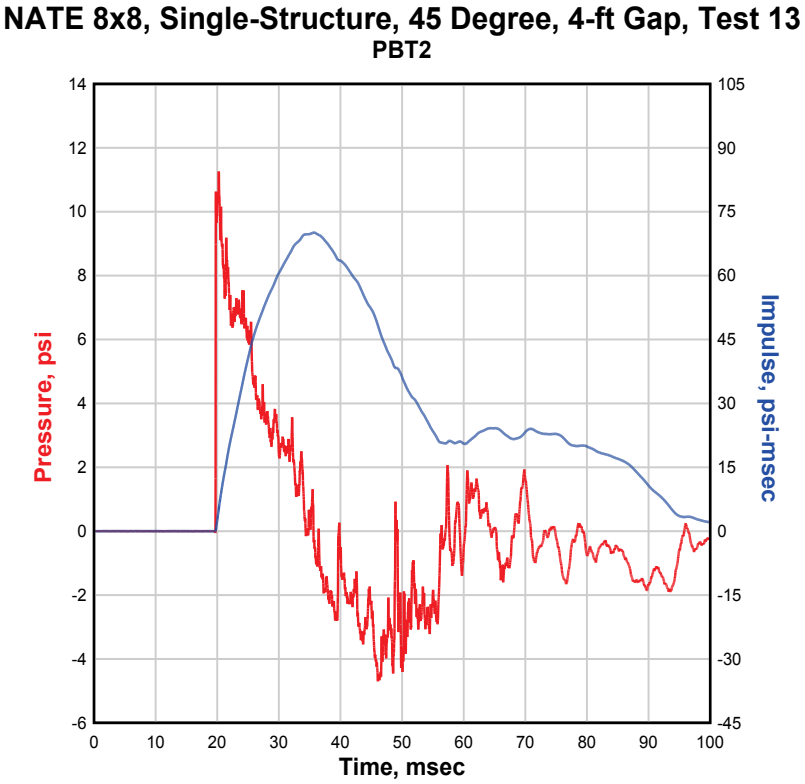

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

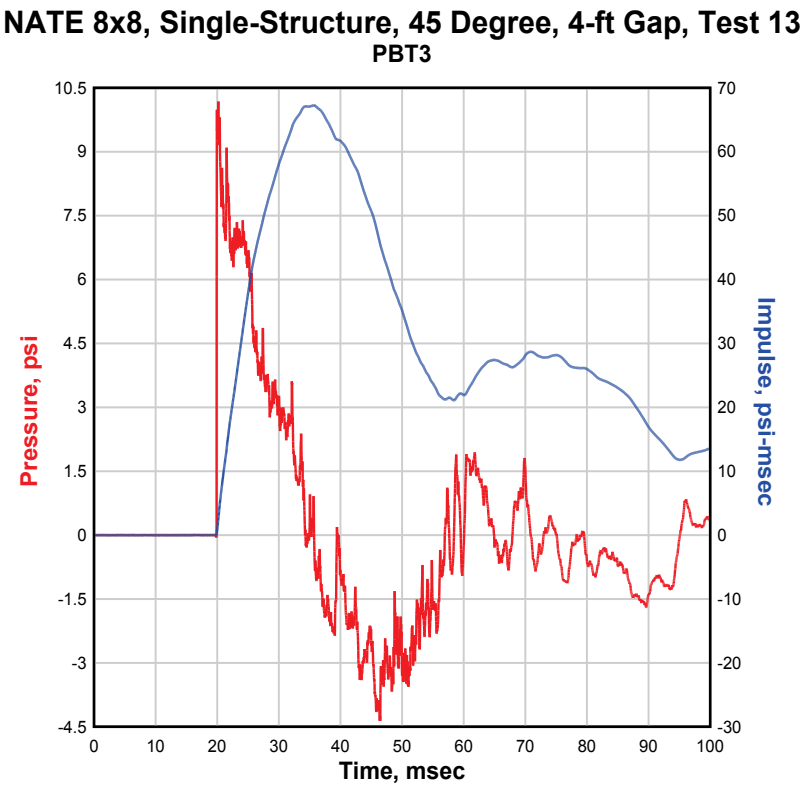

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100

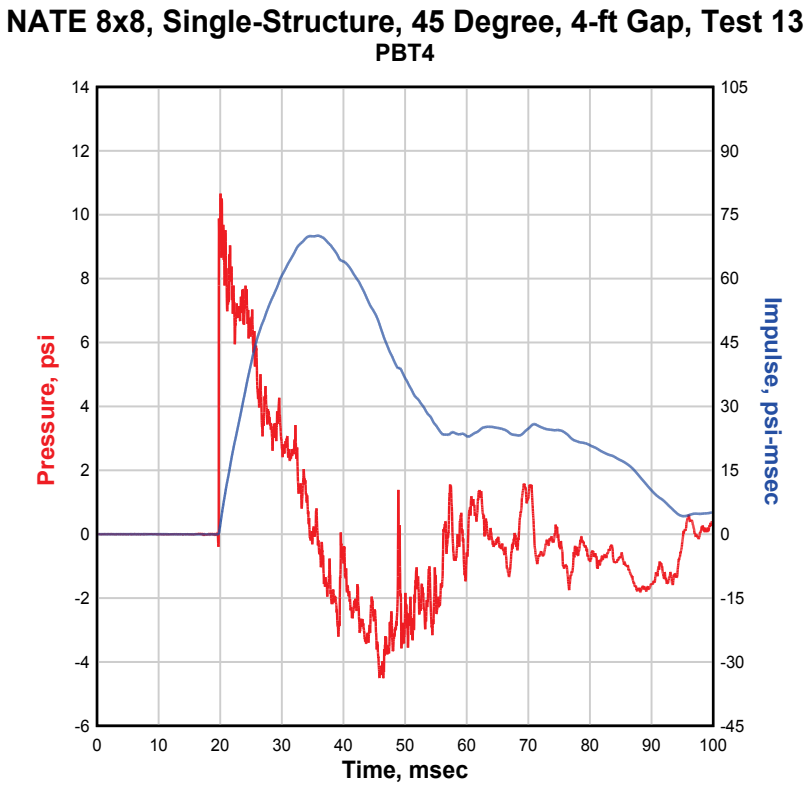

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

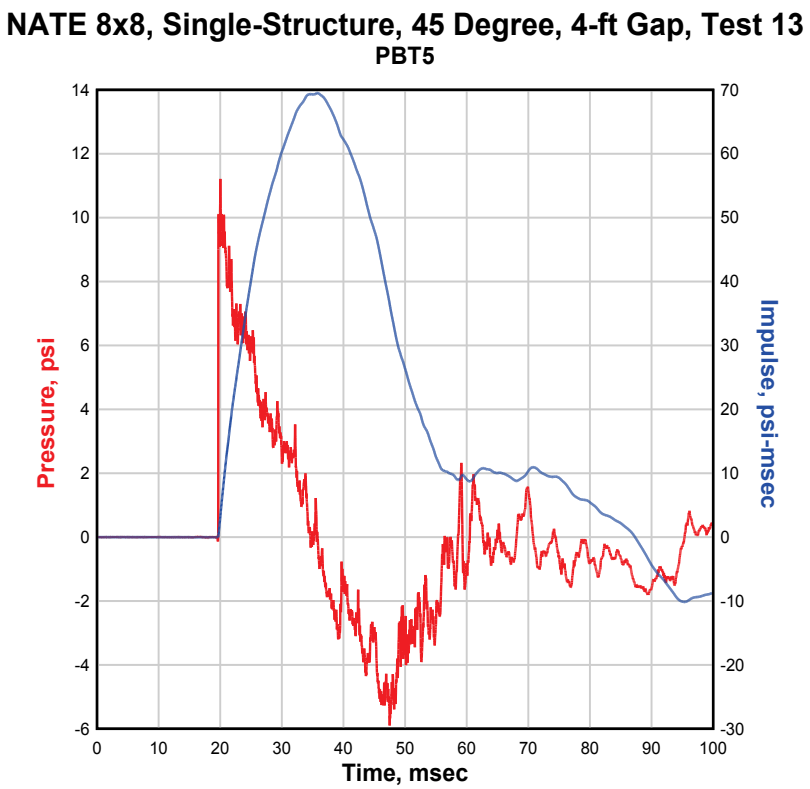

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

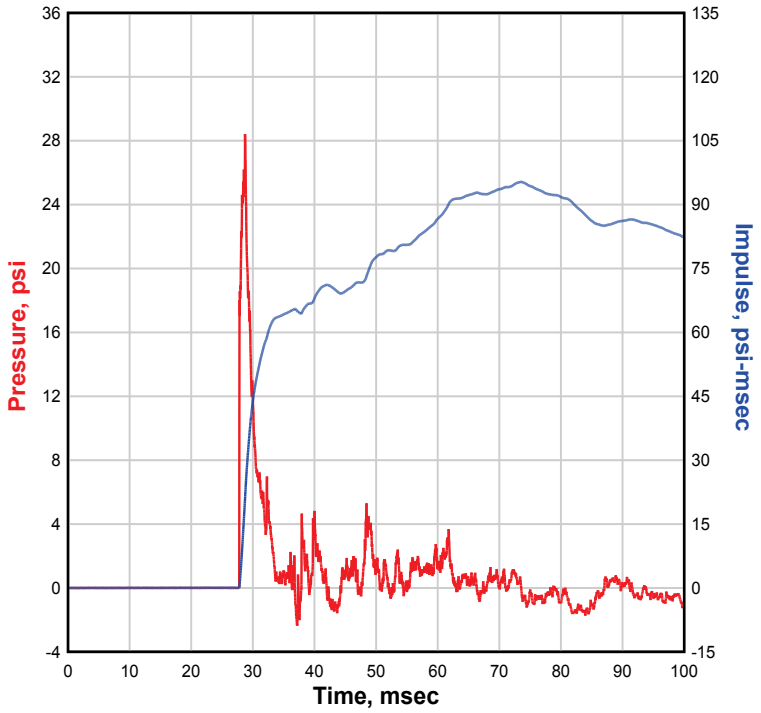

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

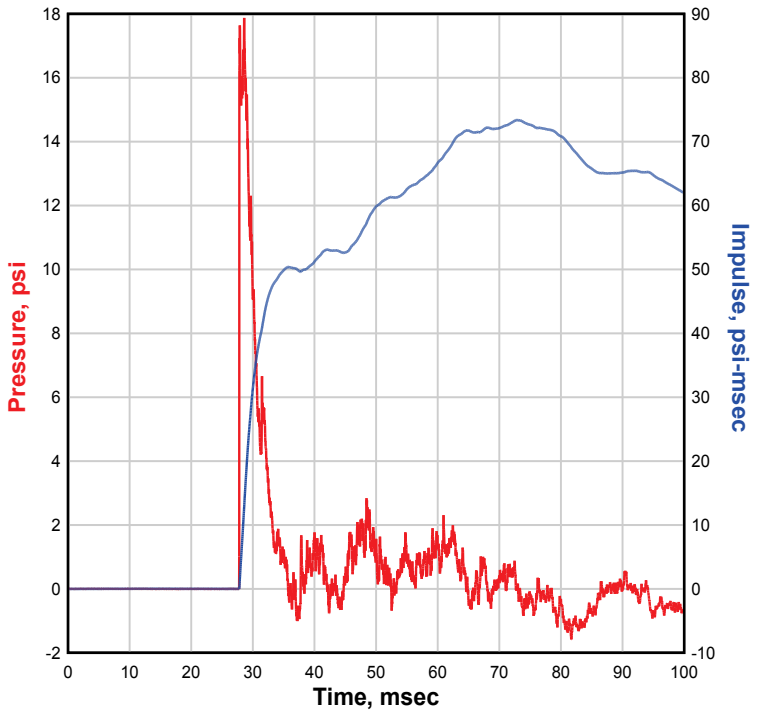

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

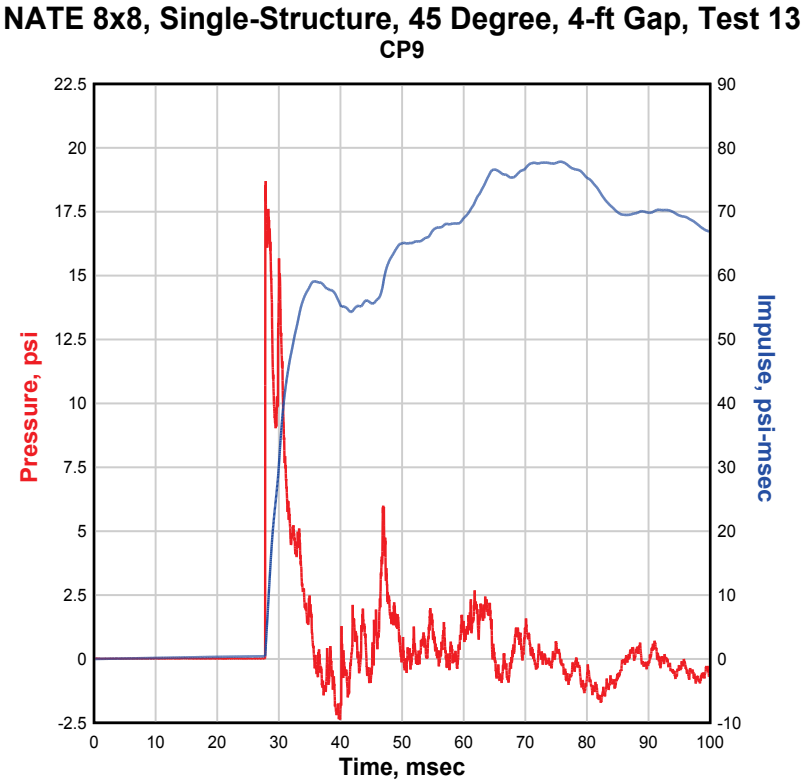

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

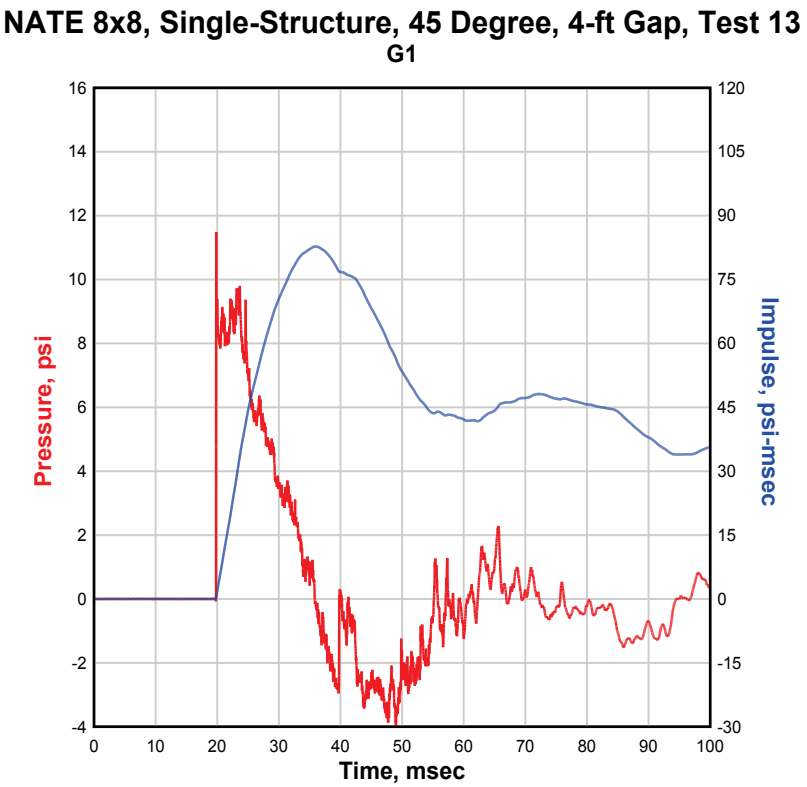
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
CP3

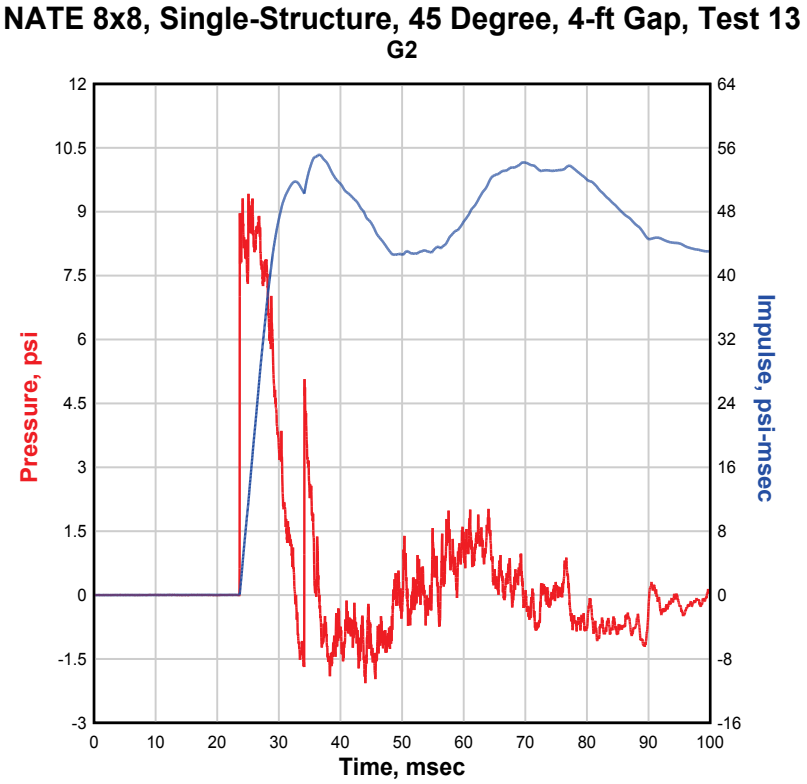


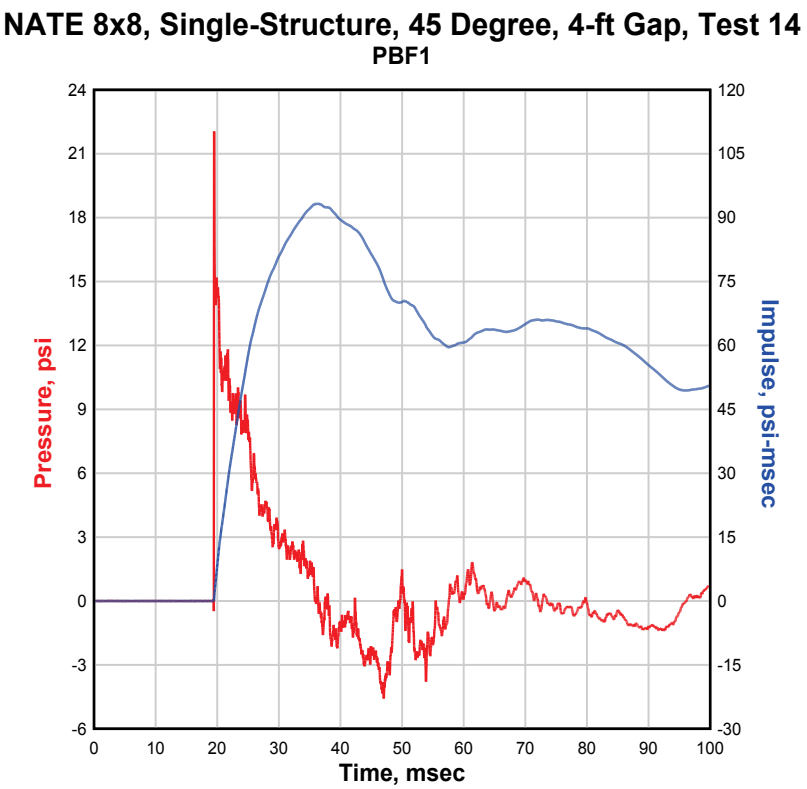
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
CP5

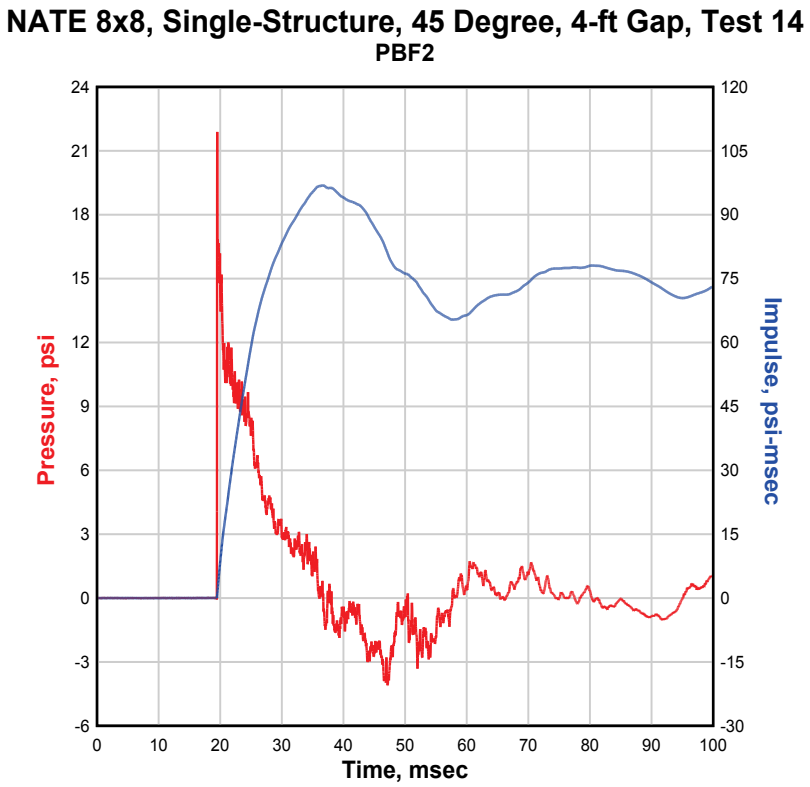


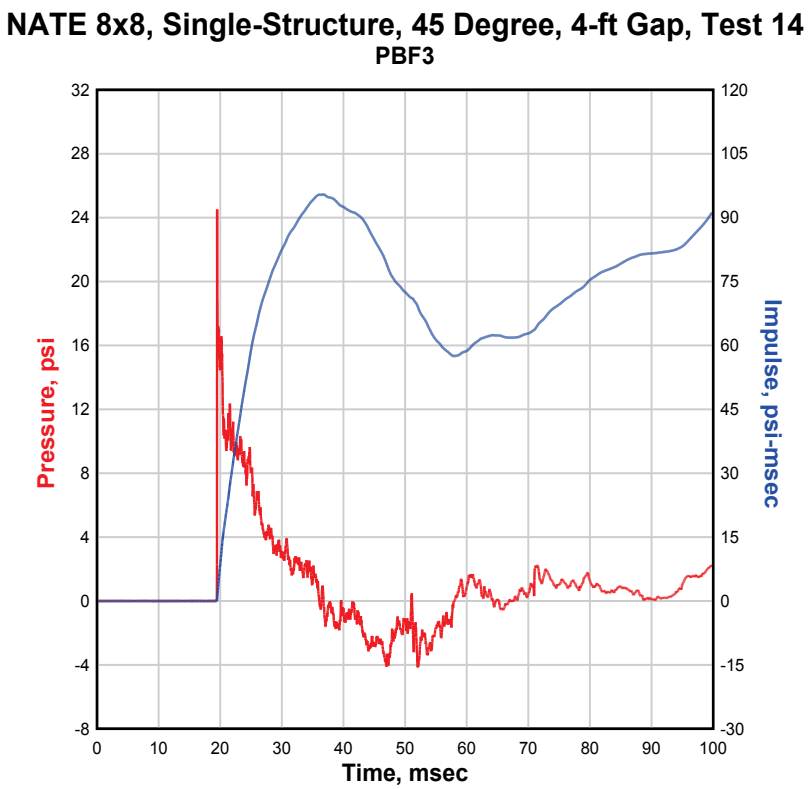

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

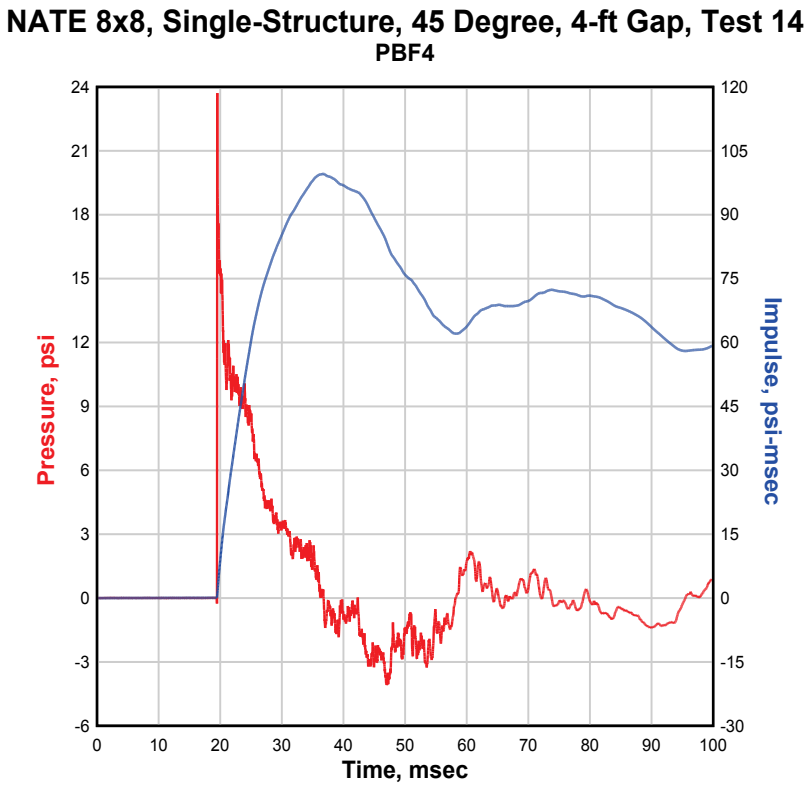

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
G1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

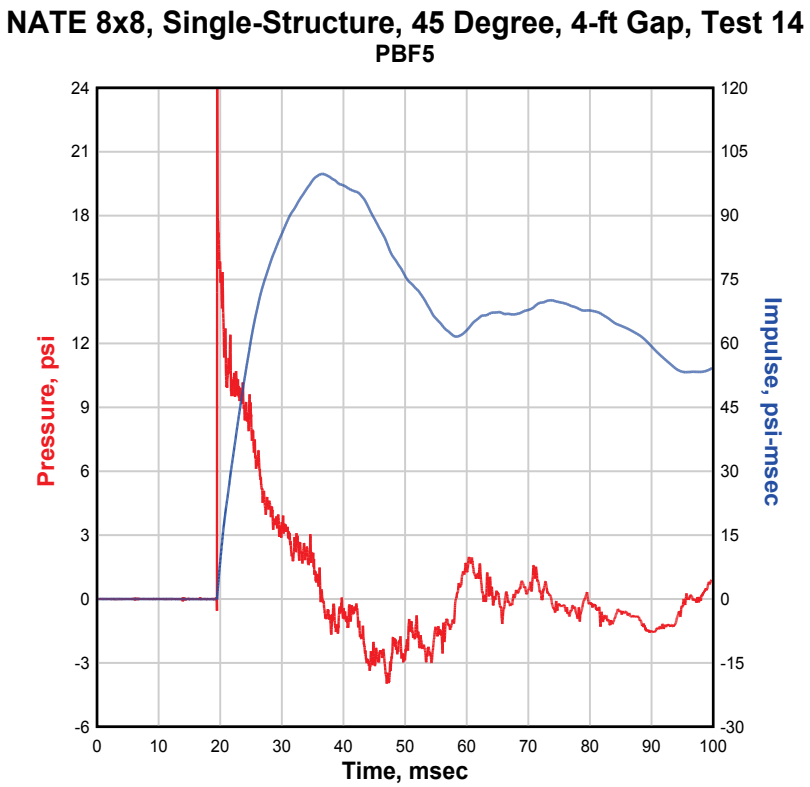

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 13
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

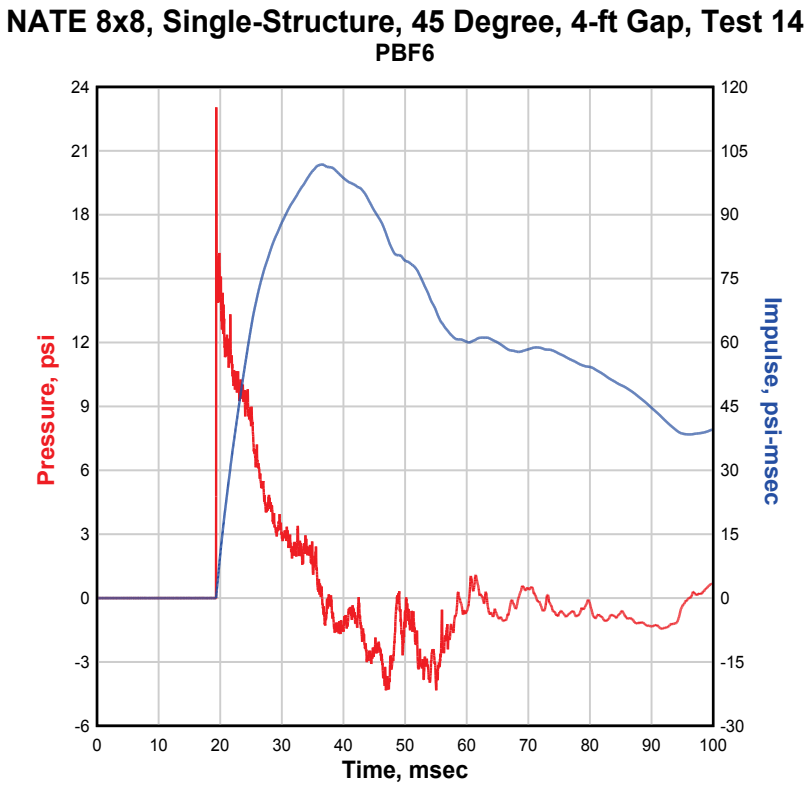

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

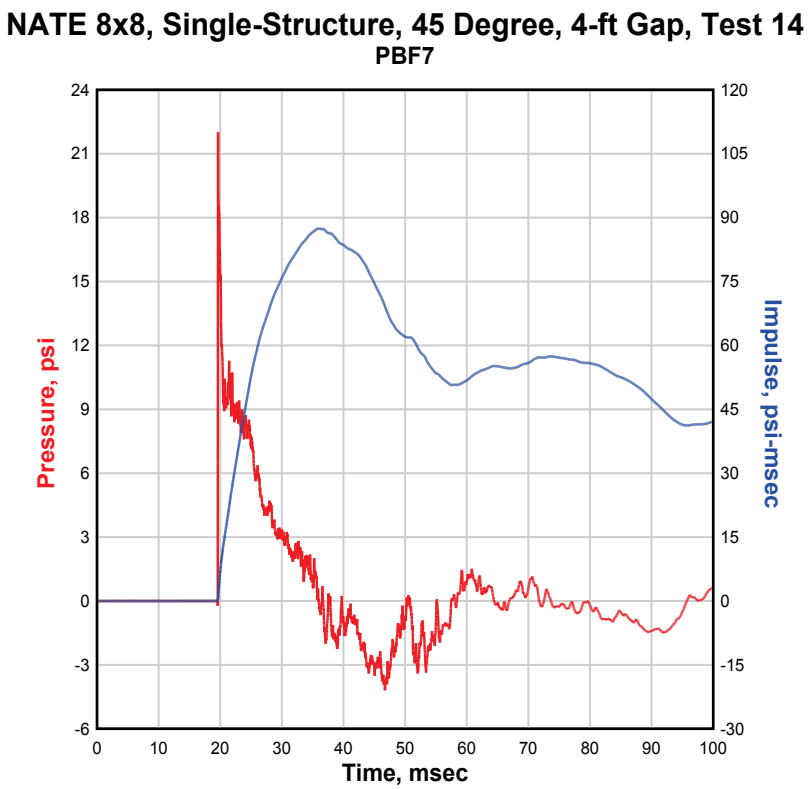

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

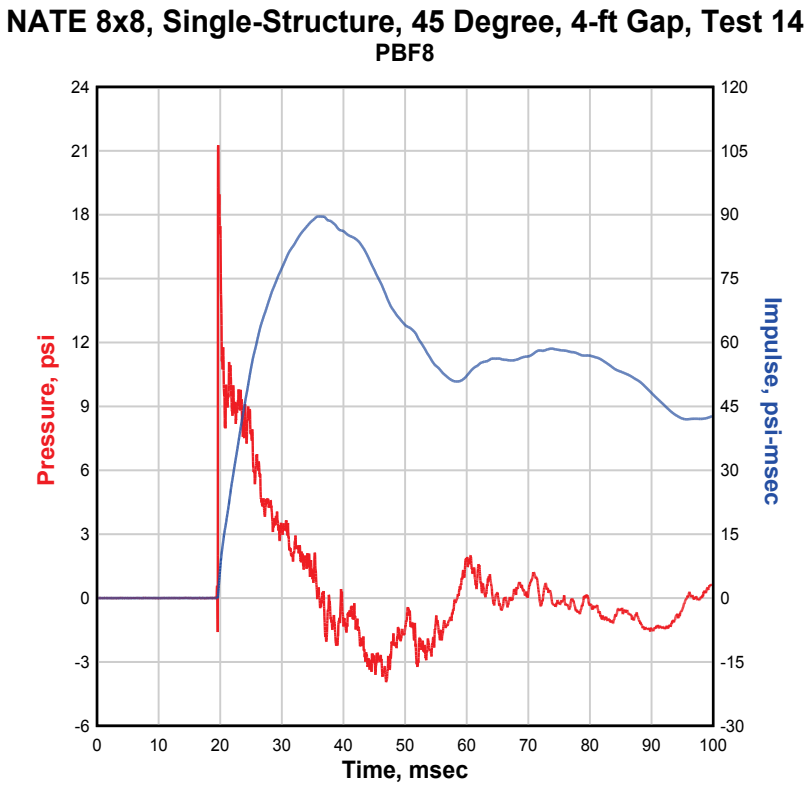

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

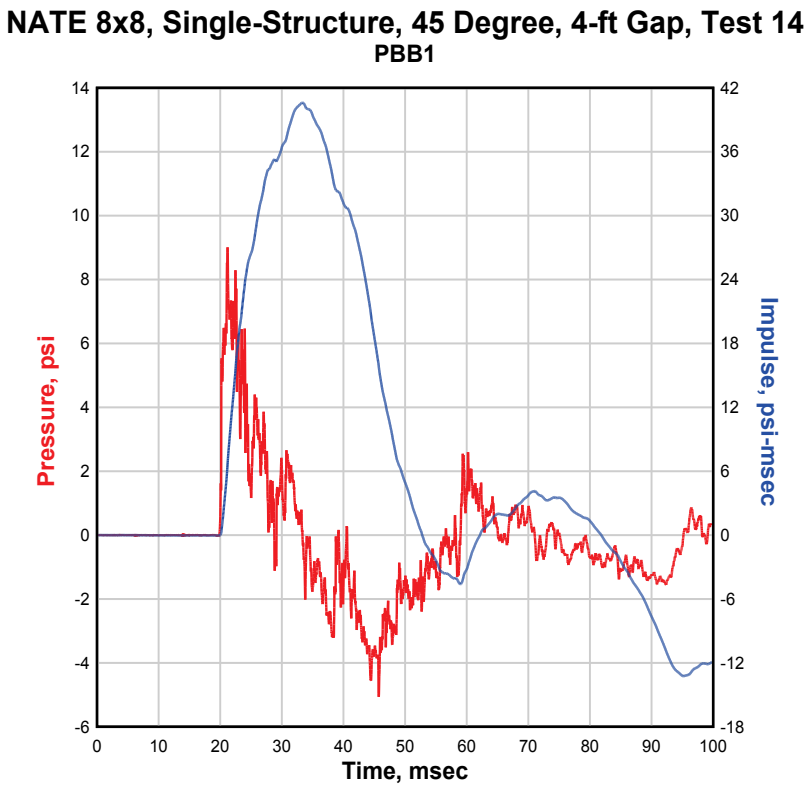

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

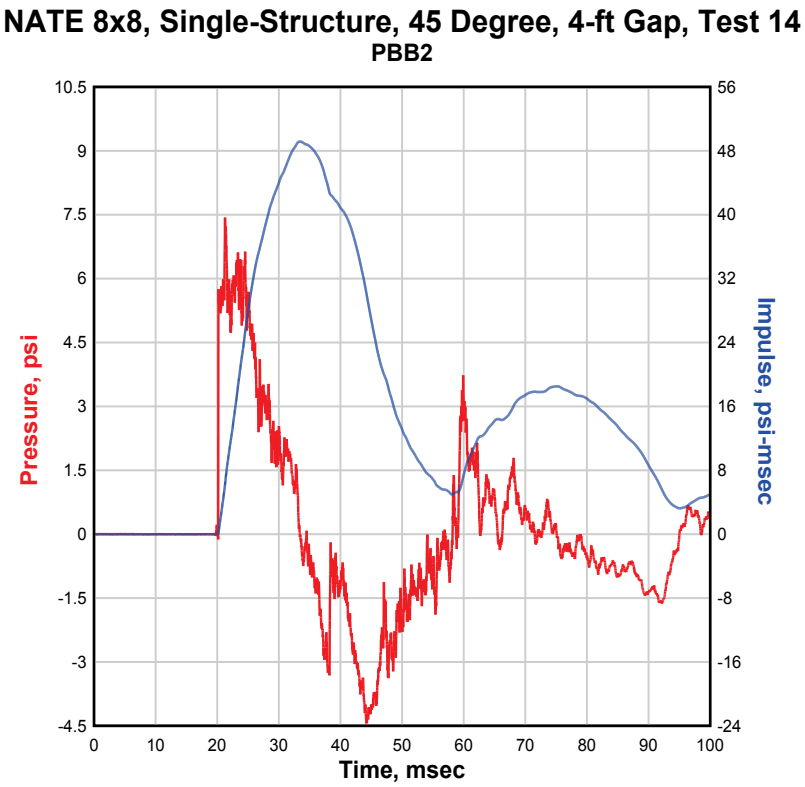

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

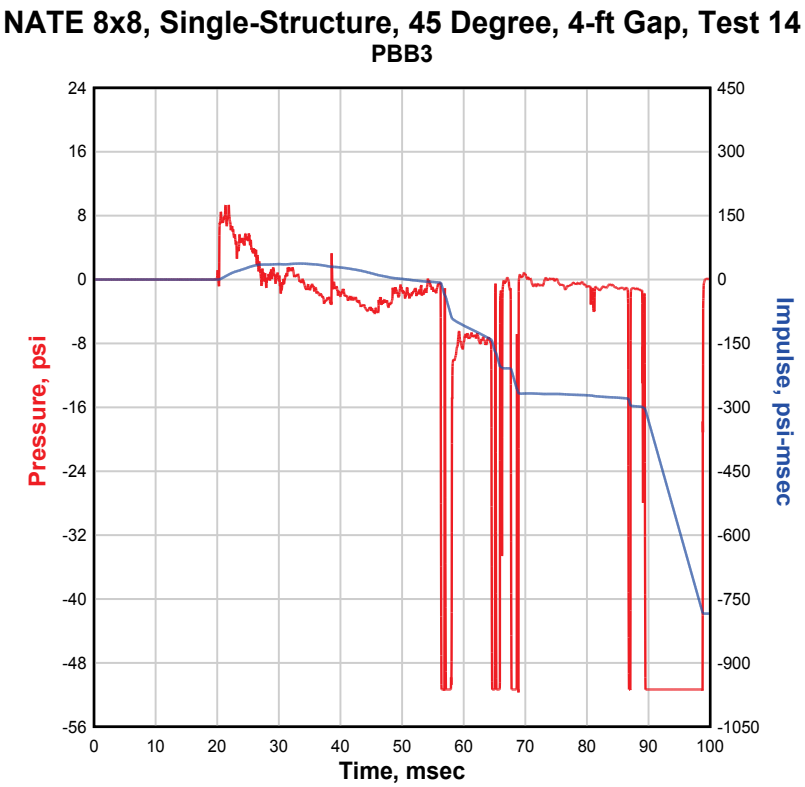

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

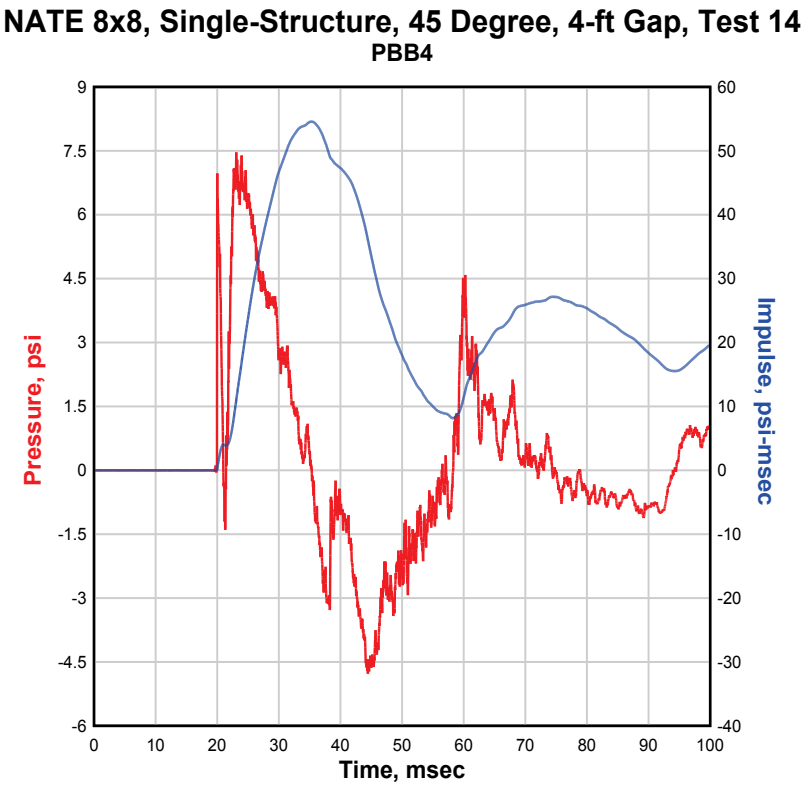

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

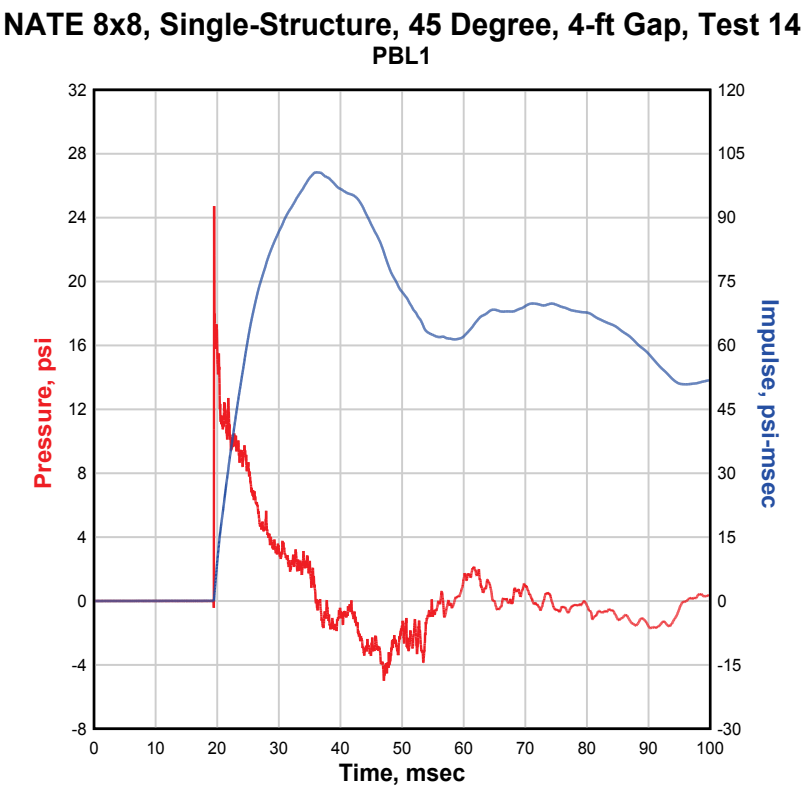

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

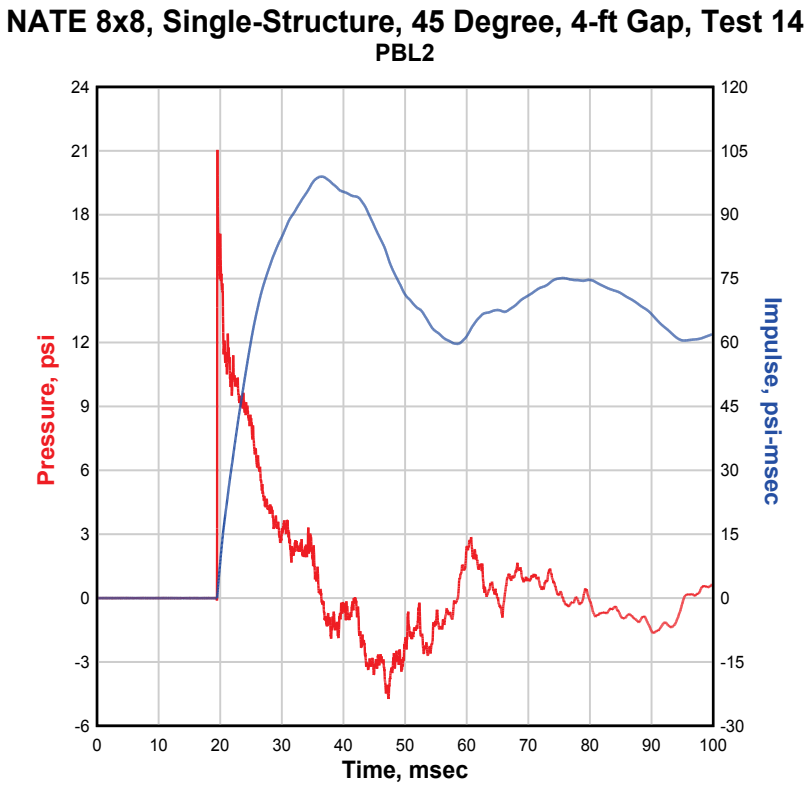

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
42
36
30
24
18
12
6
0
-6
-12
-18
0
10
20
30
40
50
60
70
80
90
100

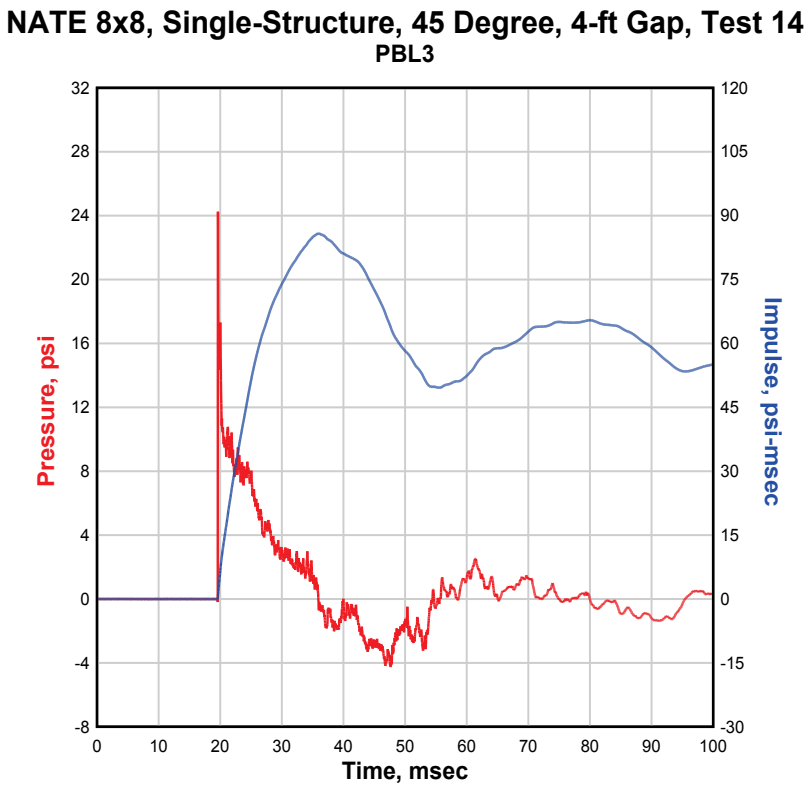

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

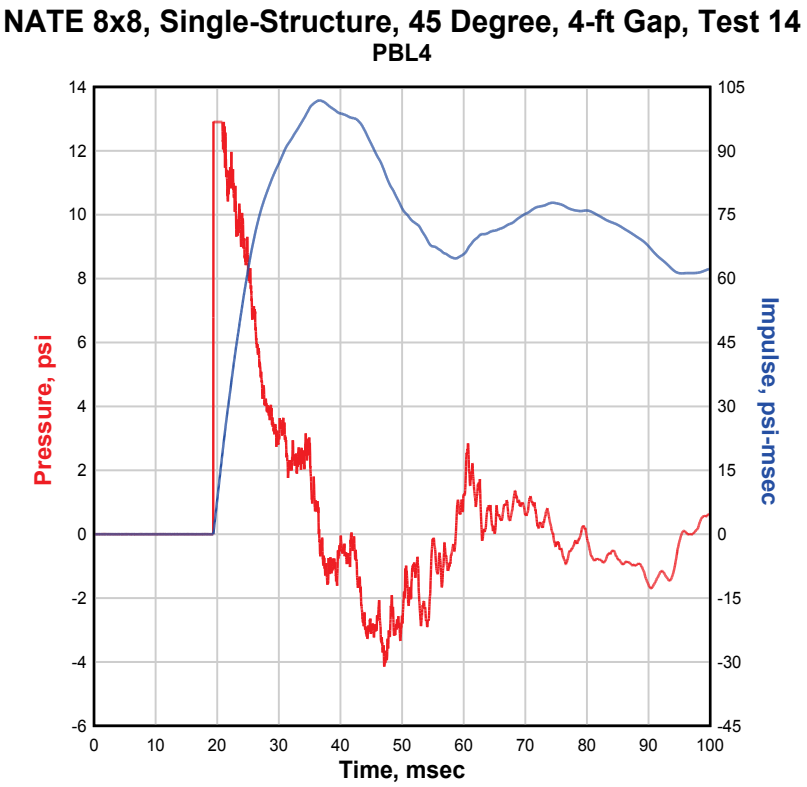

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
450
300
150
0
-150
-300
-450
-600
-750
-900
-1050
0
10
20
30
40
50
60
70
80
90
100

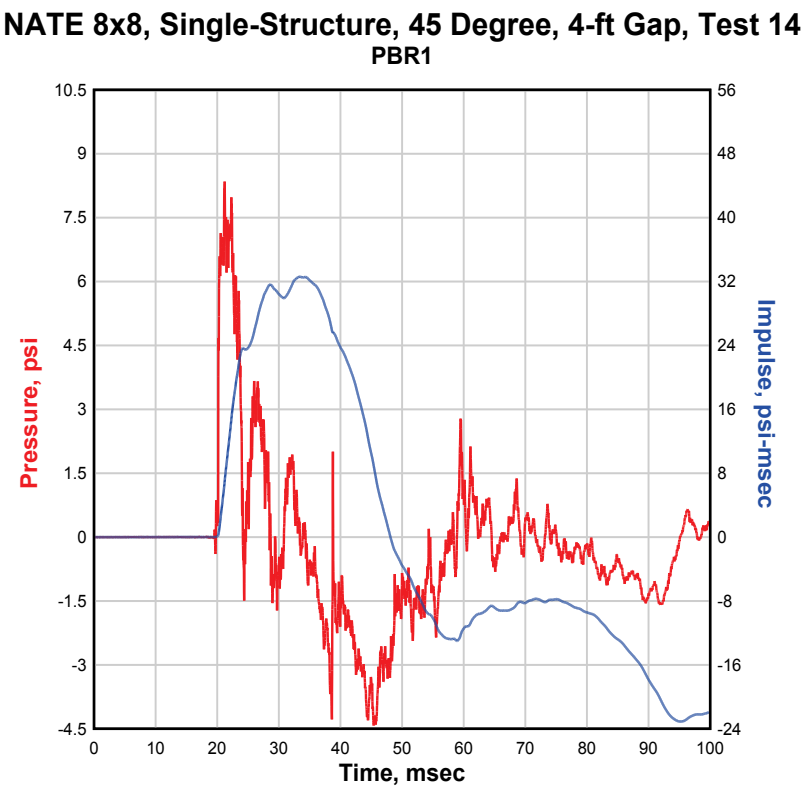

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100

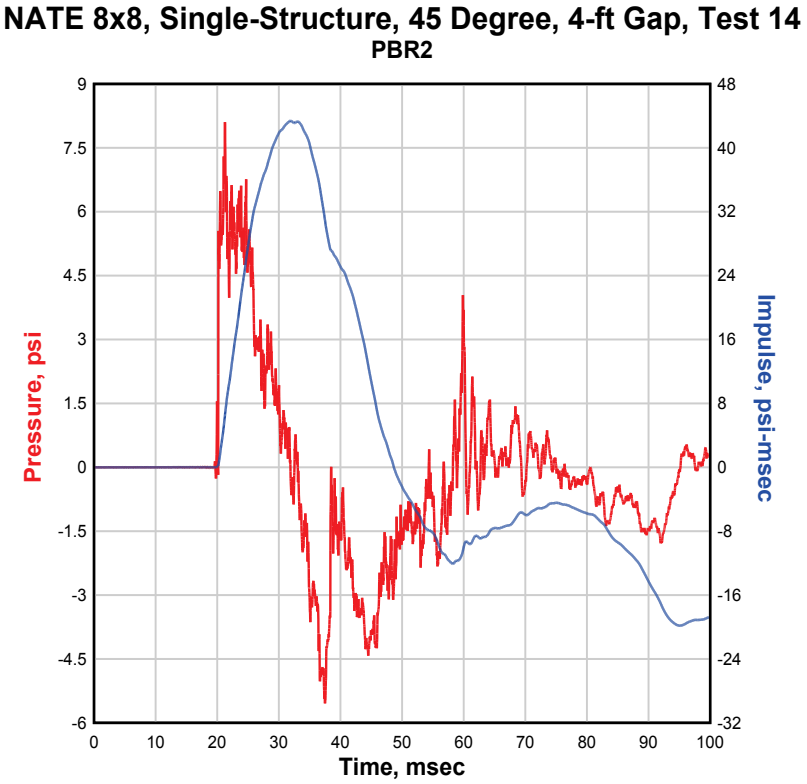

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

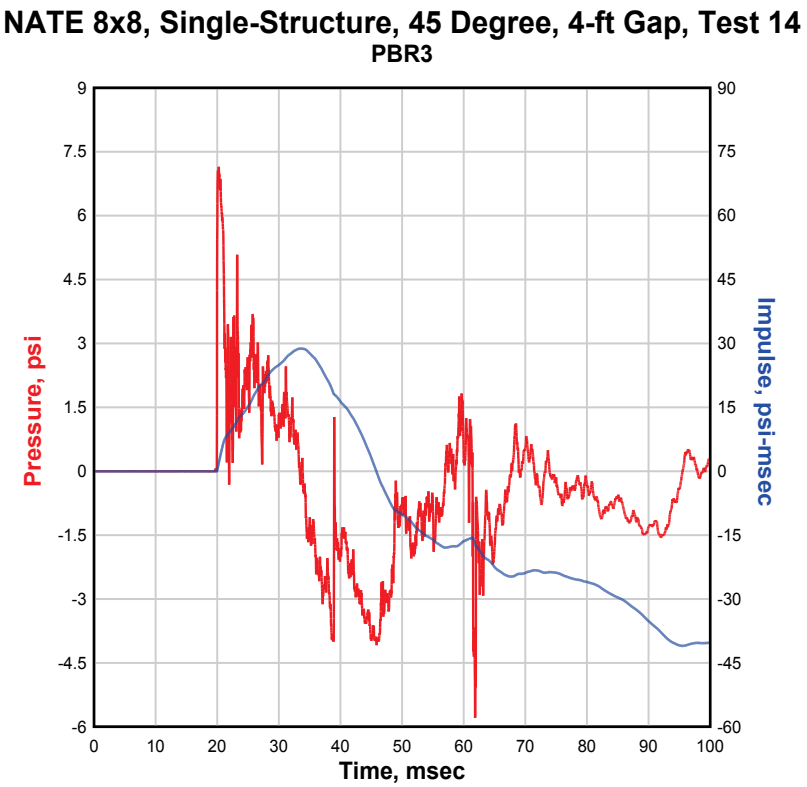

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
90
75
60
45
30
15
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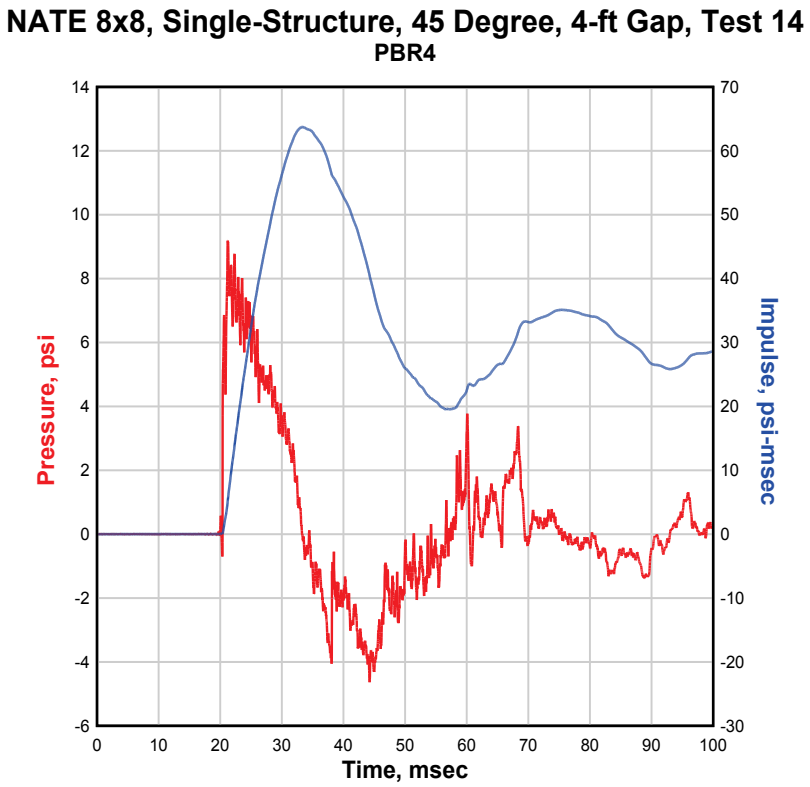
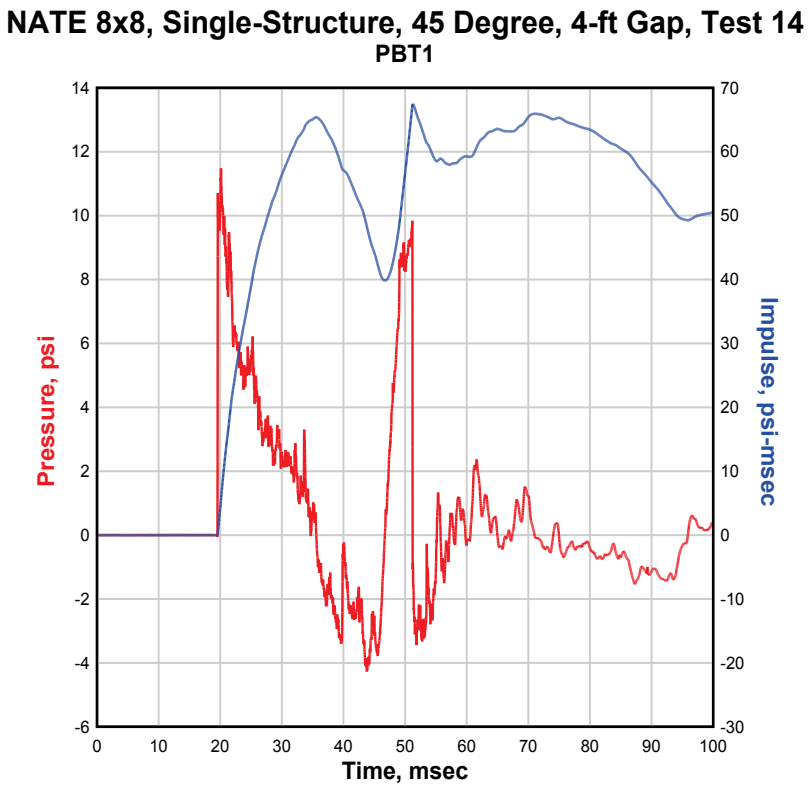
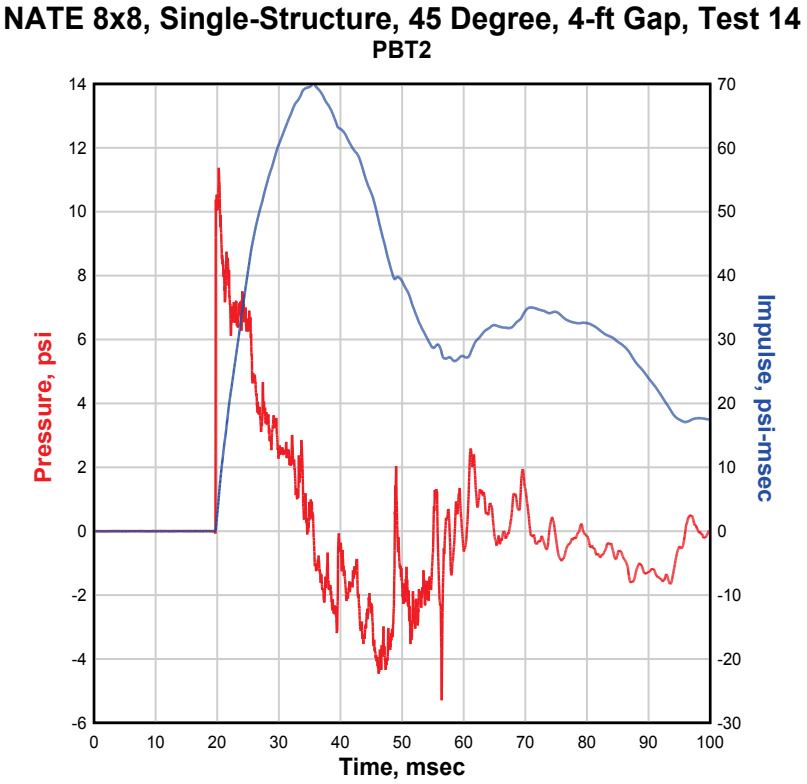
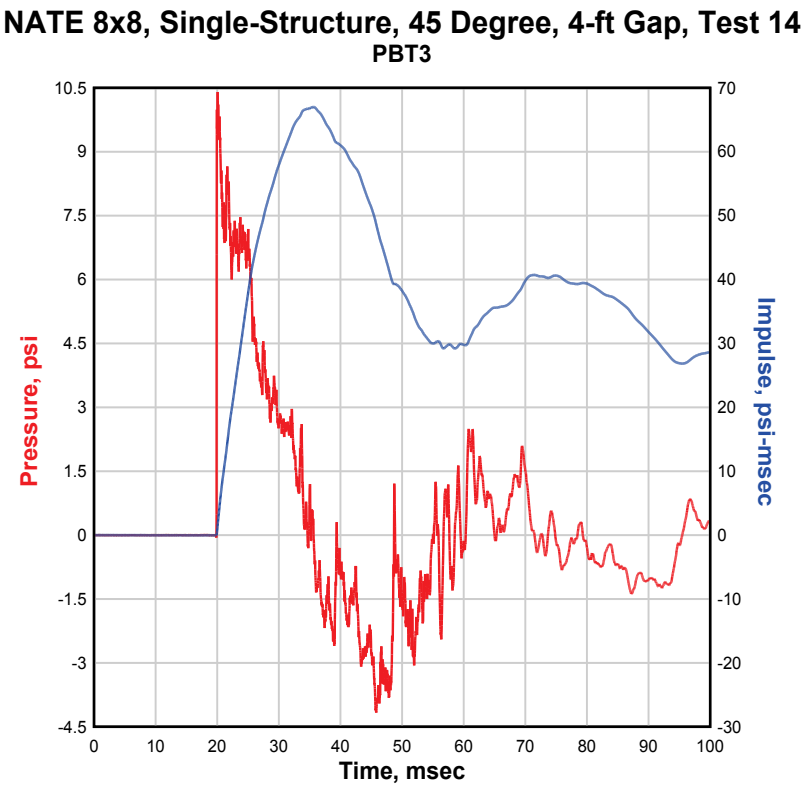
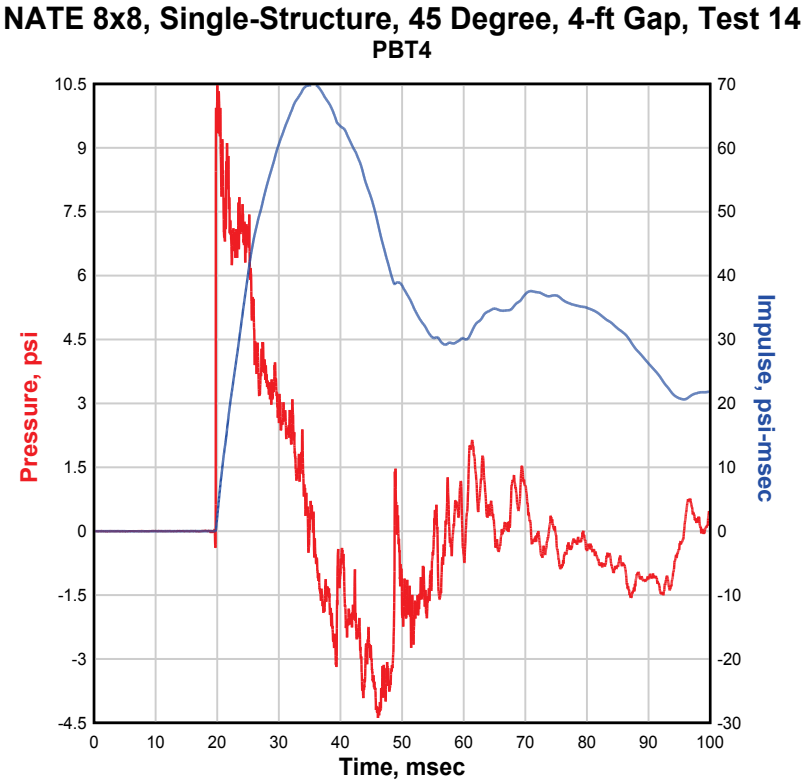
-15
-30
-45
-60
0
10
20
30
40
50
60
70
80
90
100

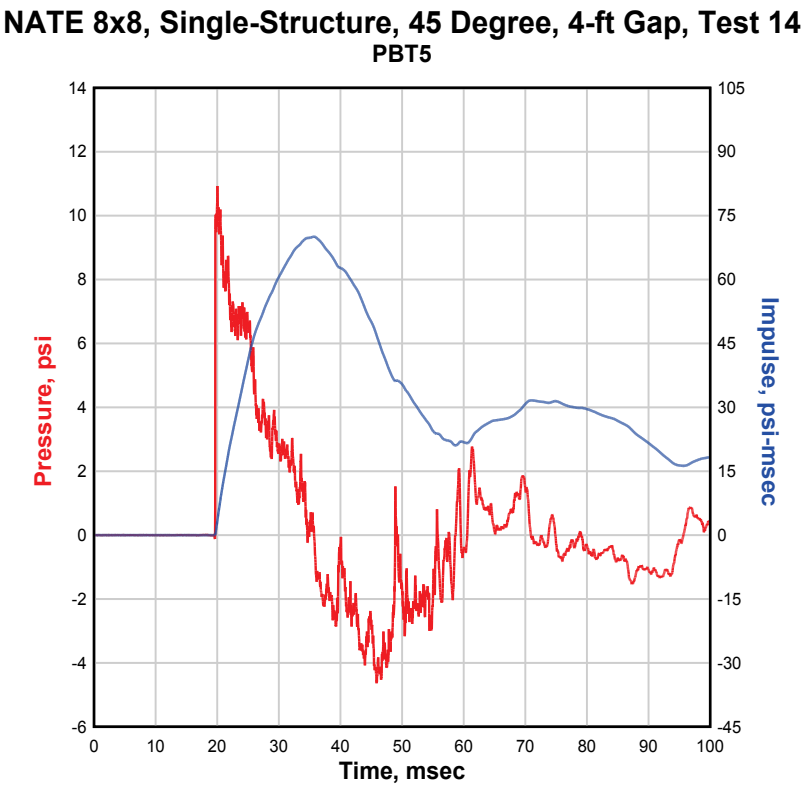

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

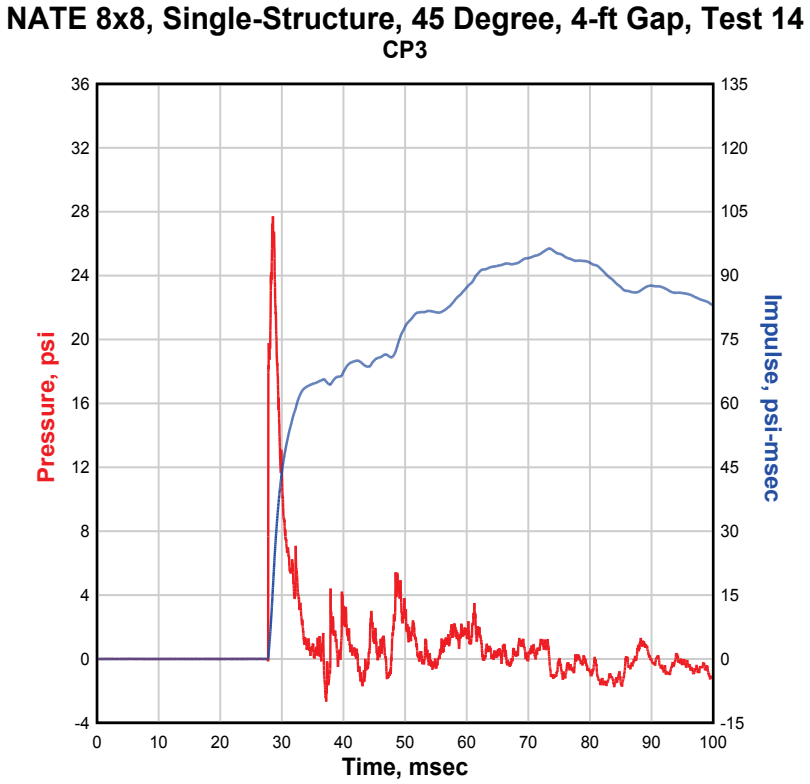

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

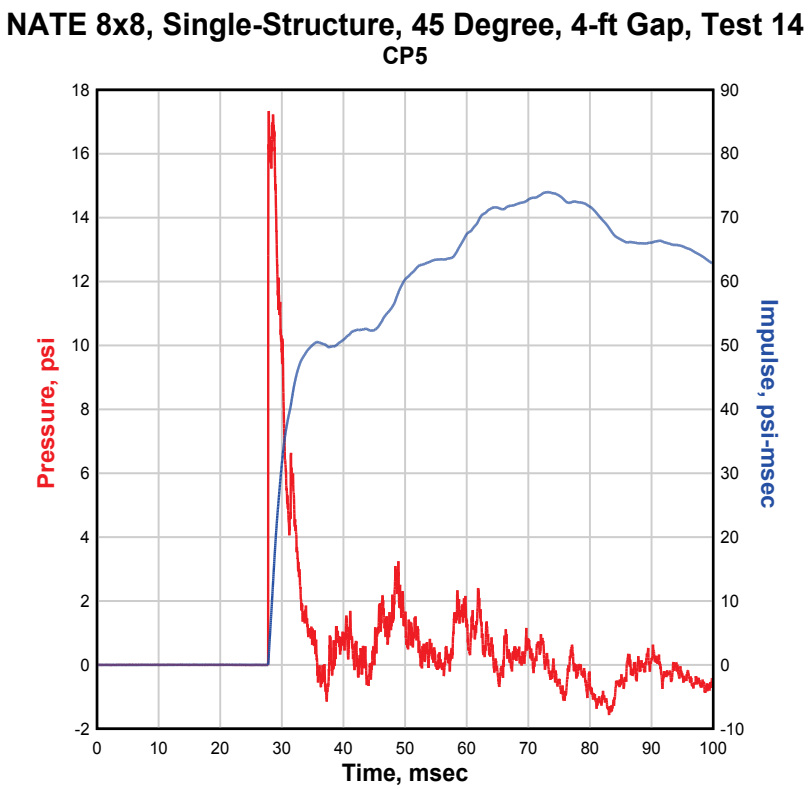

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

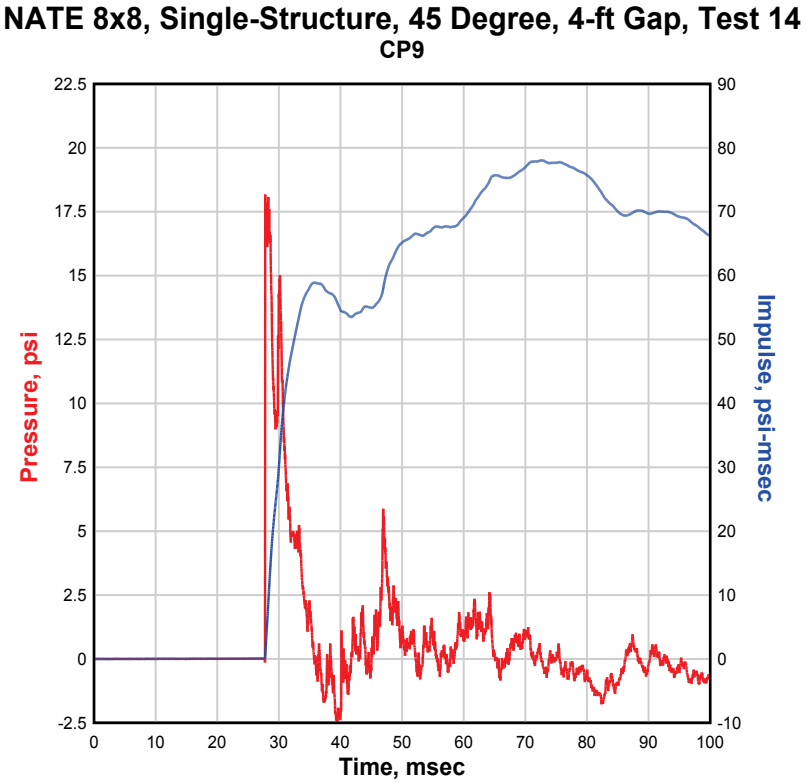

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

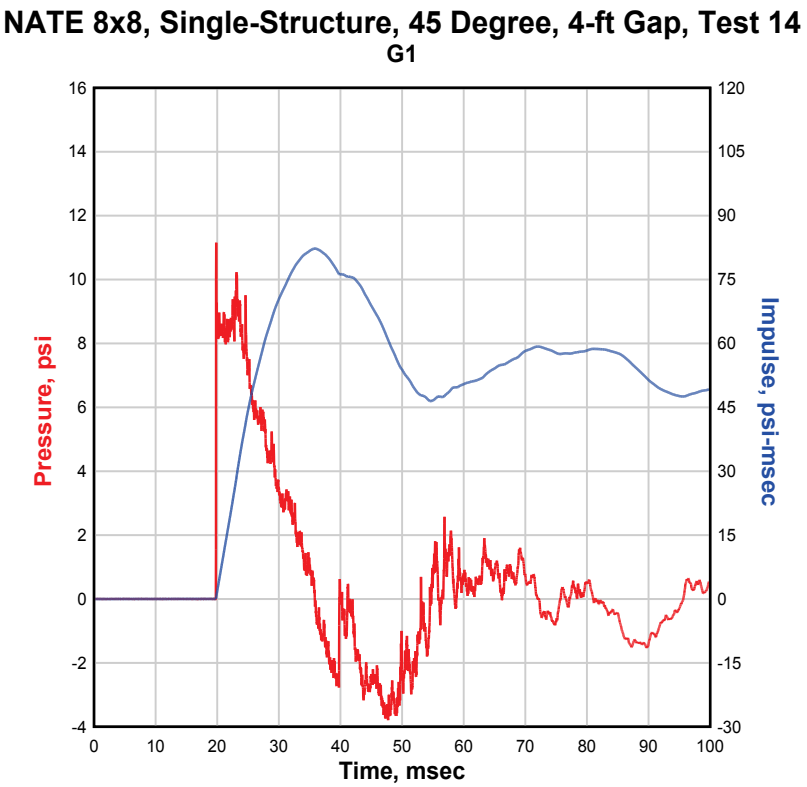

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

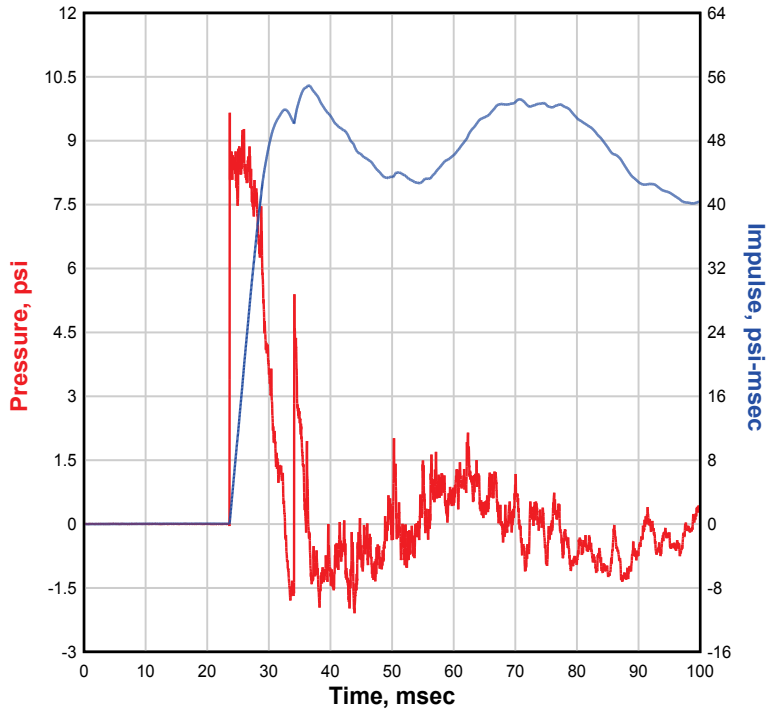

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
18
16
14
12
10
8
6
4
2
0
-2
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

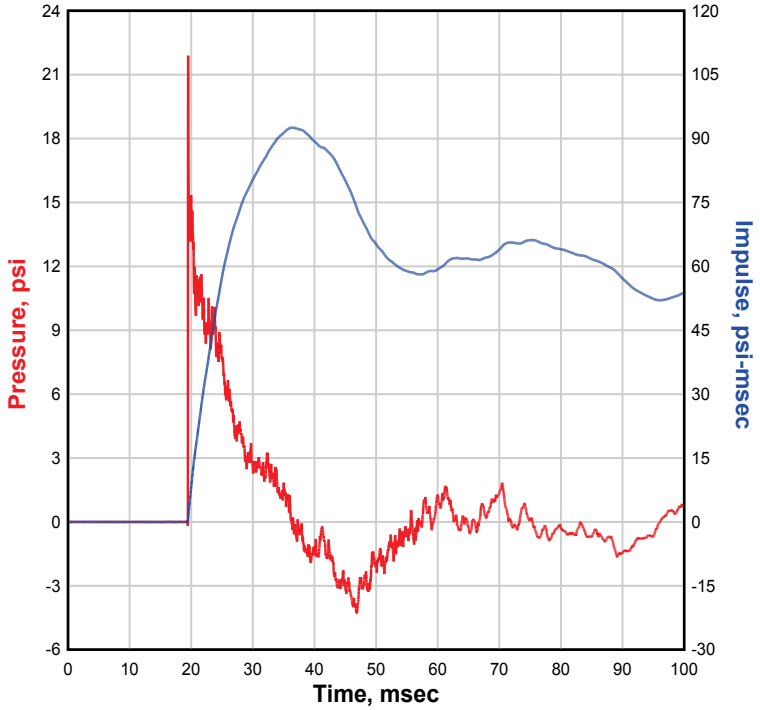

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
G1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

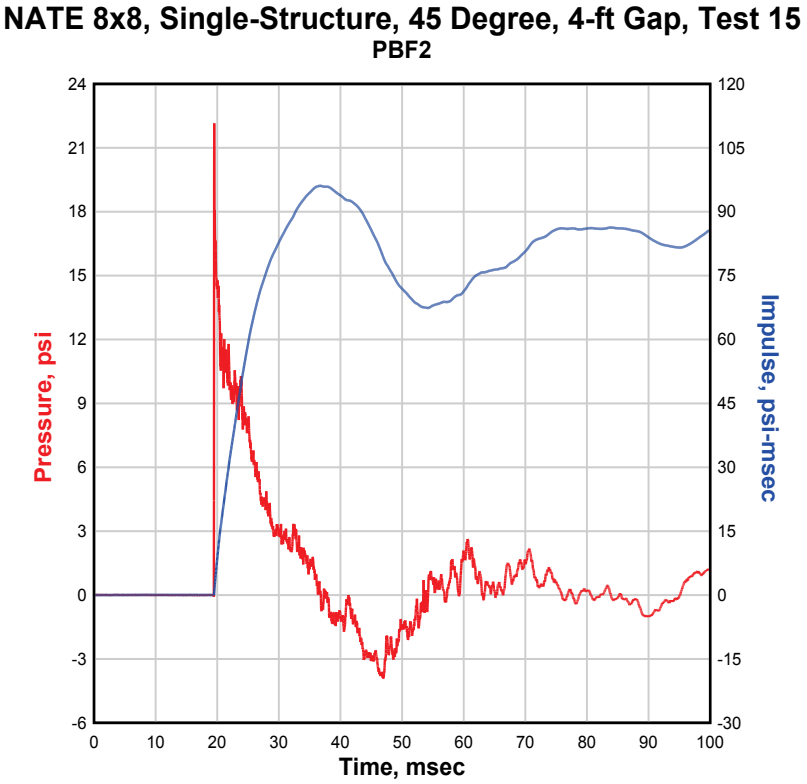
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 14
G2

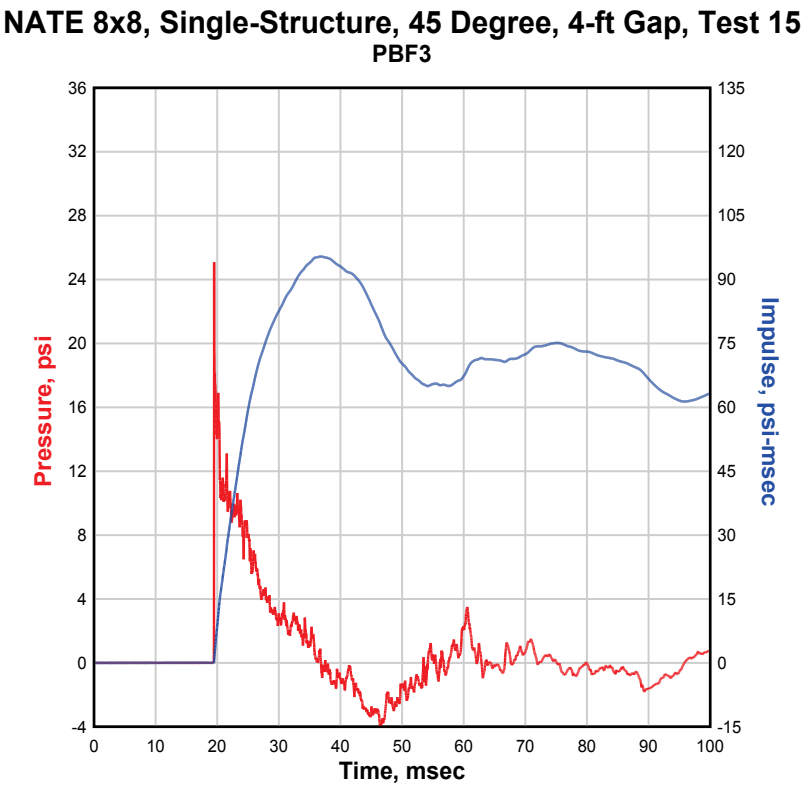


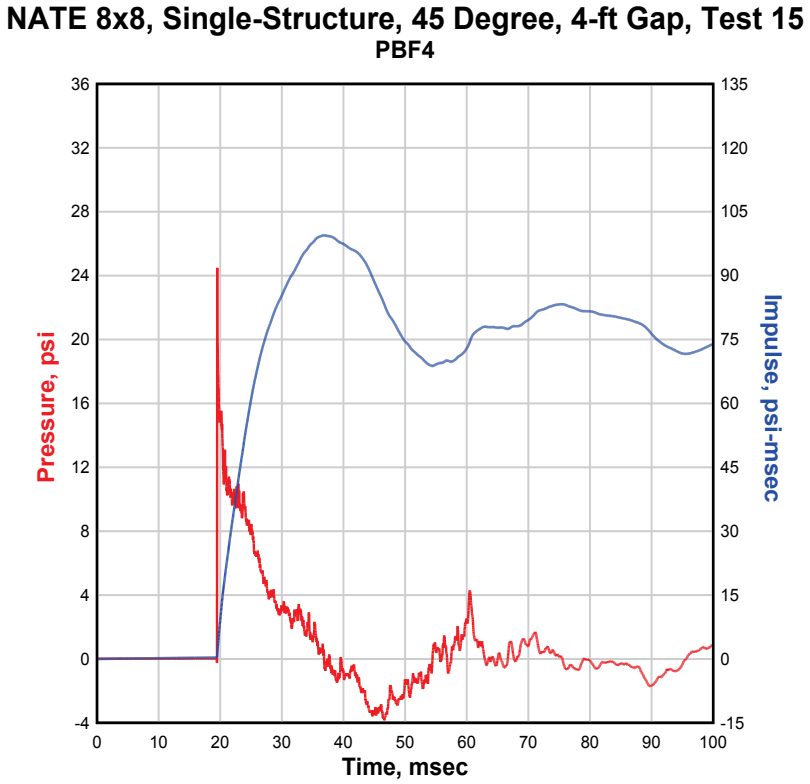
PBF4-NATE 8x8, Single-Structure, 45 deg, 4-ft Gap, Test 4_avg20.GRF

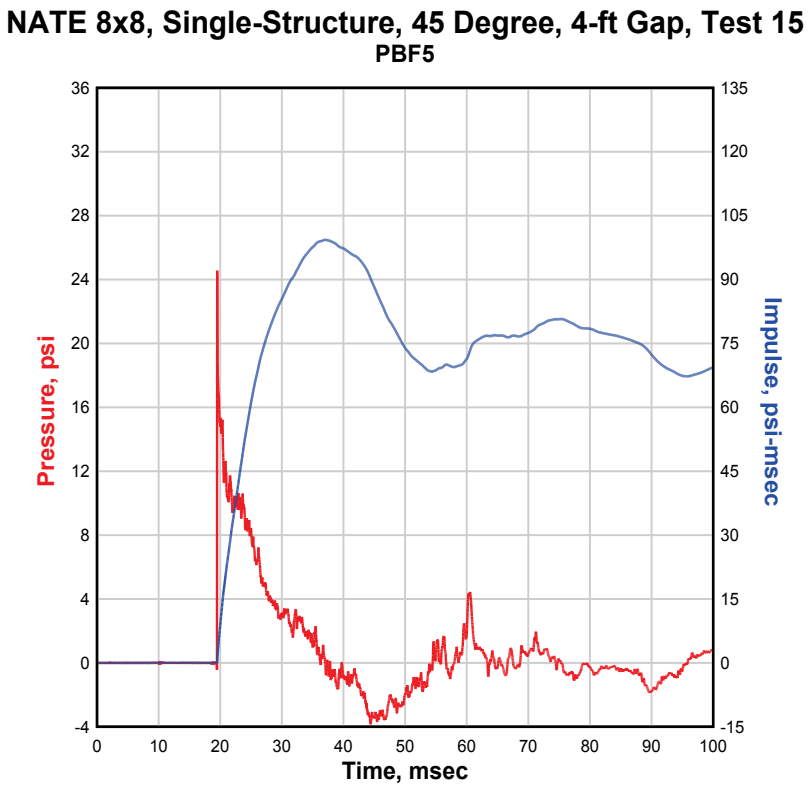
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBF1

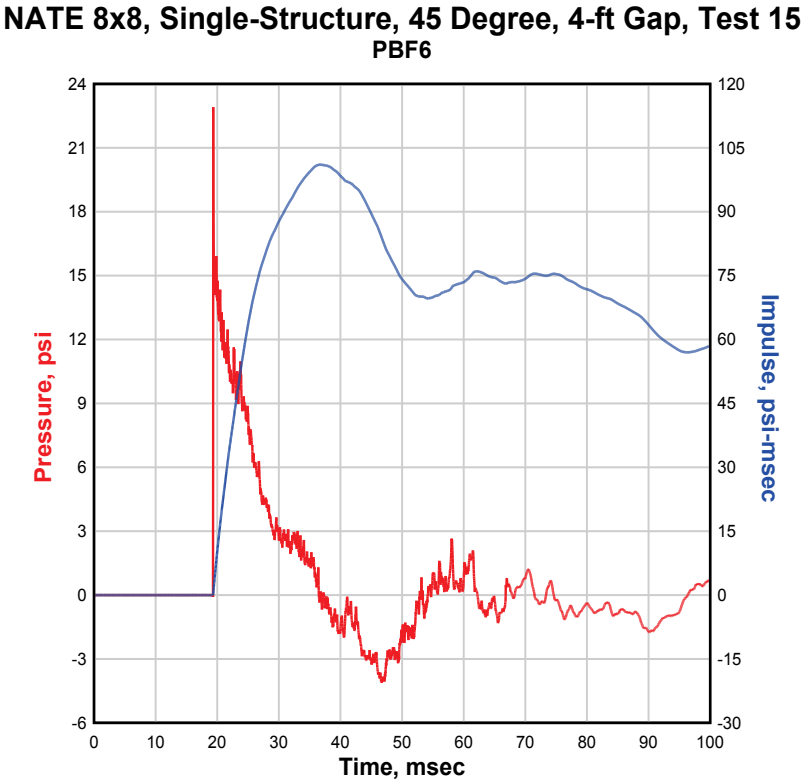


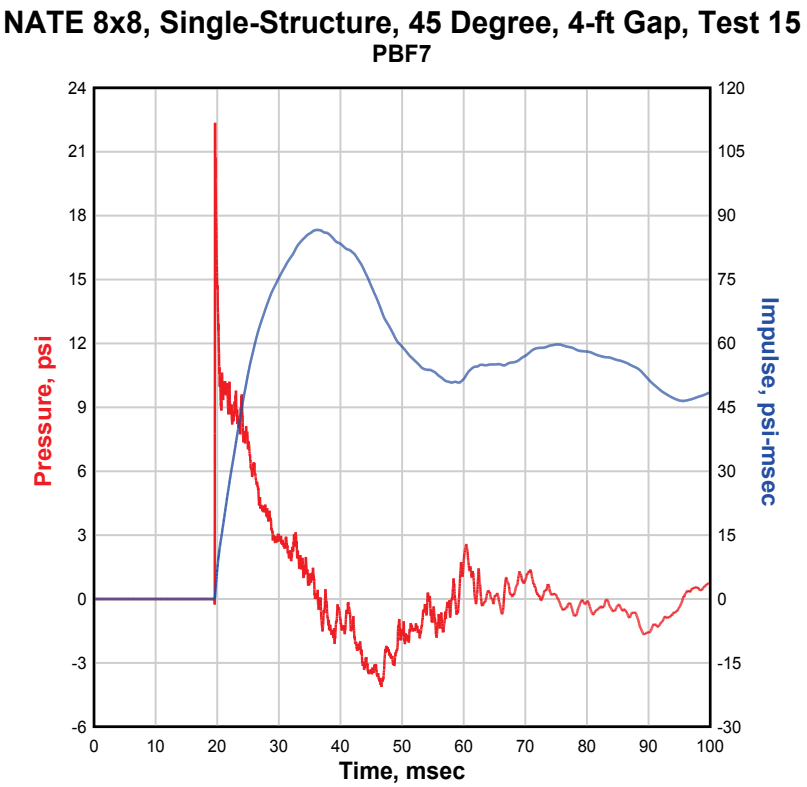

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

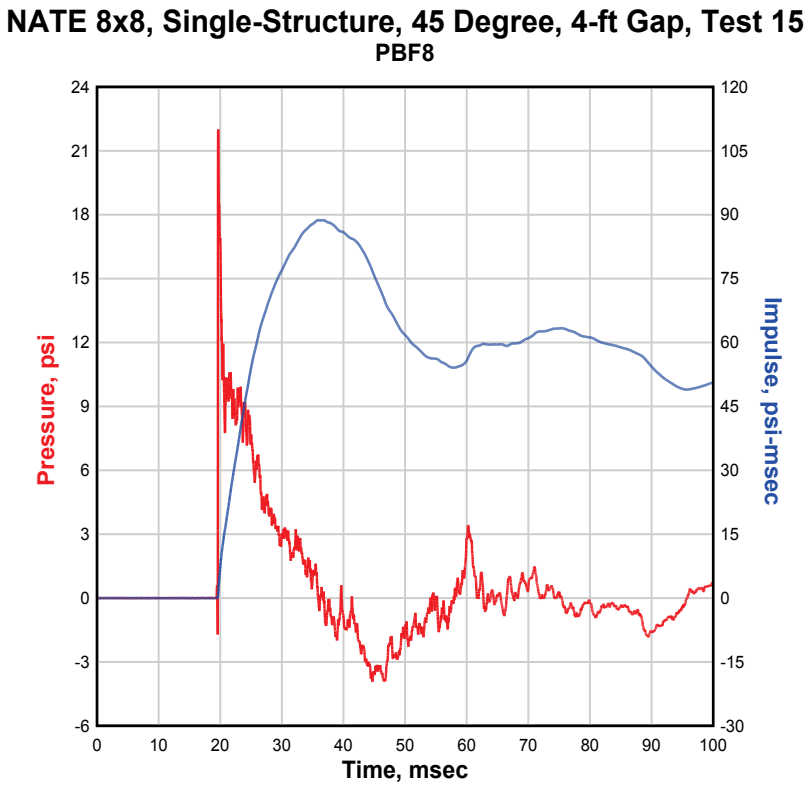

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

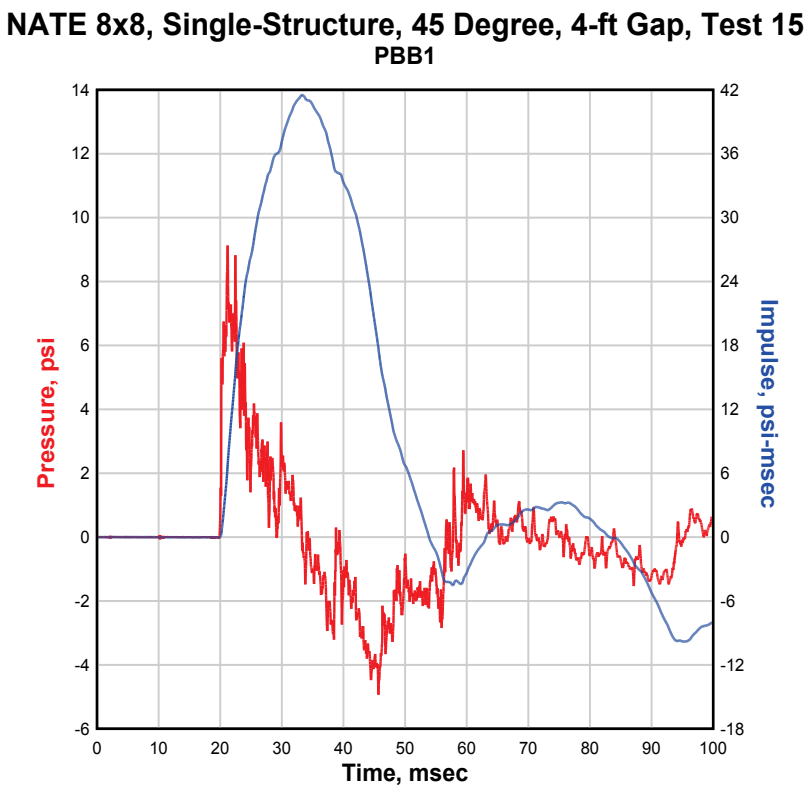

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

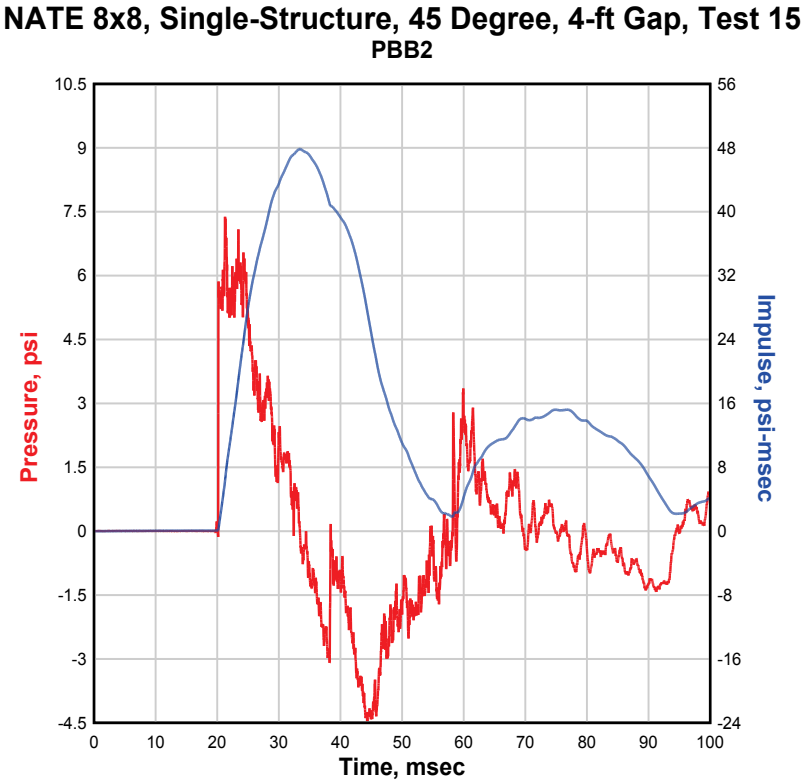

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

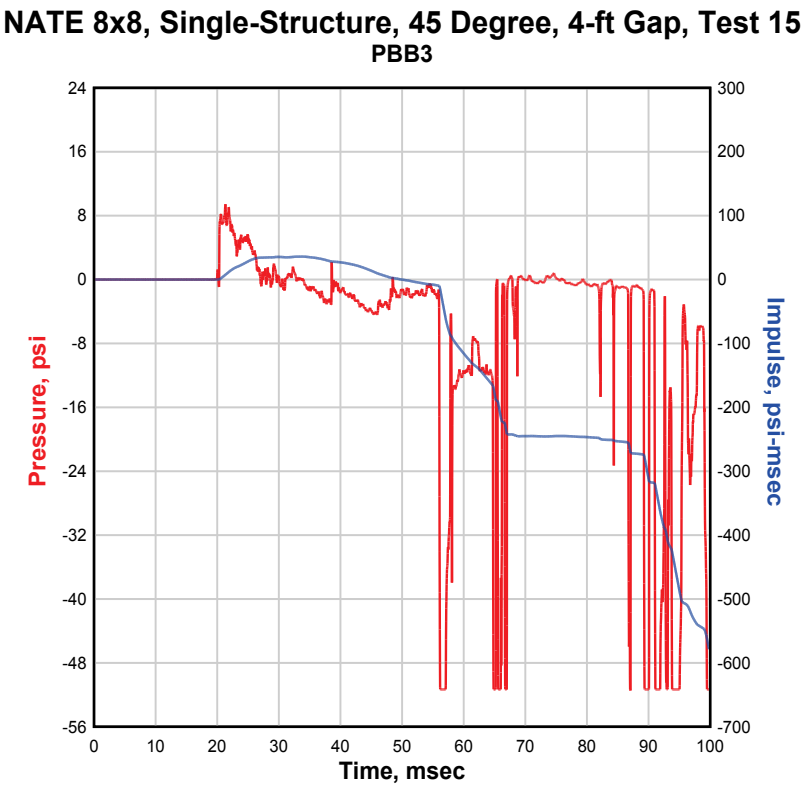

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

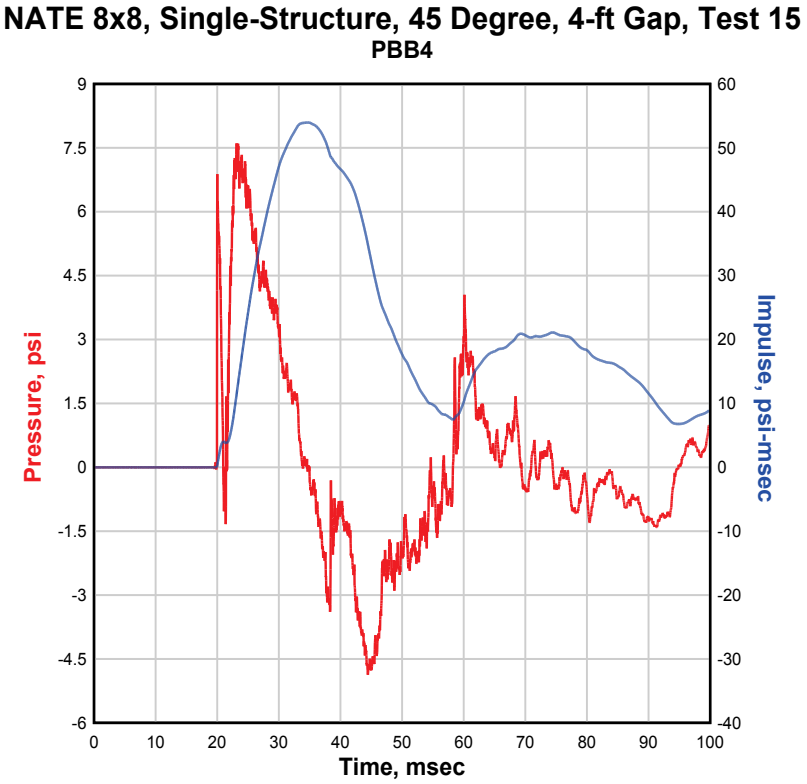

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

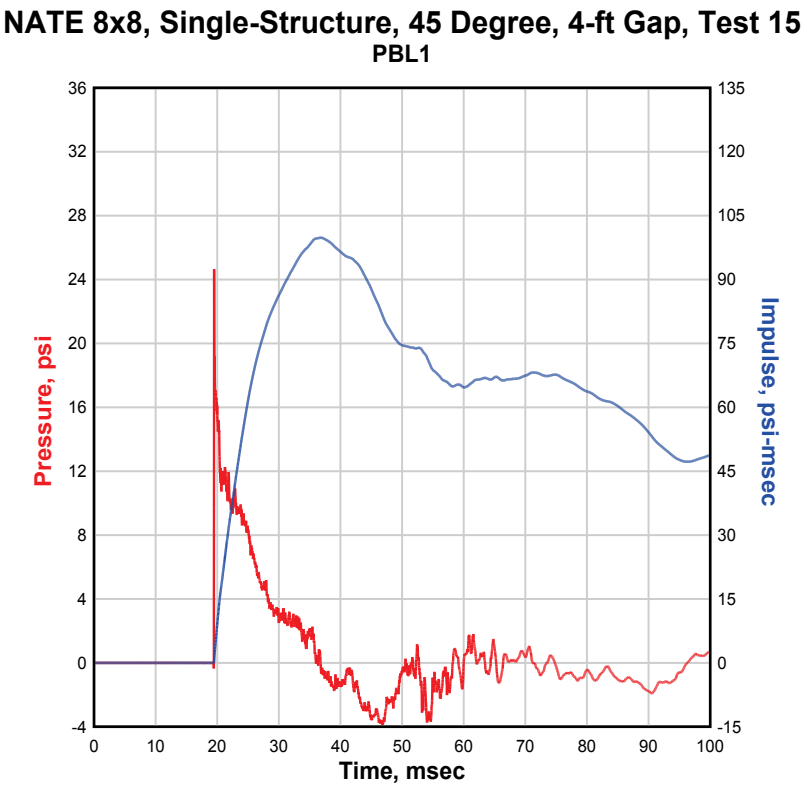

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

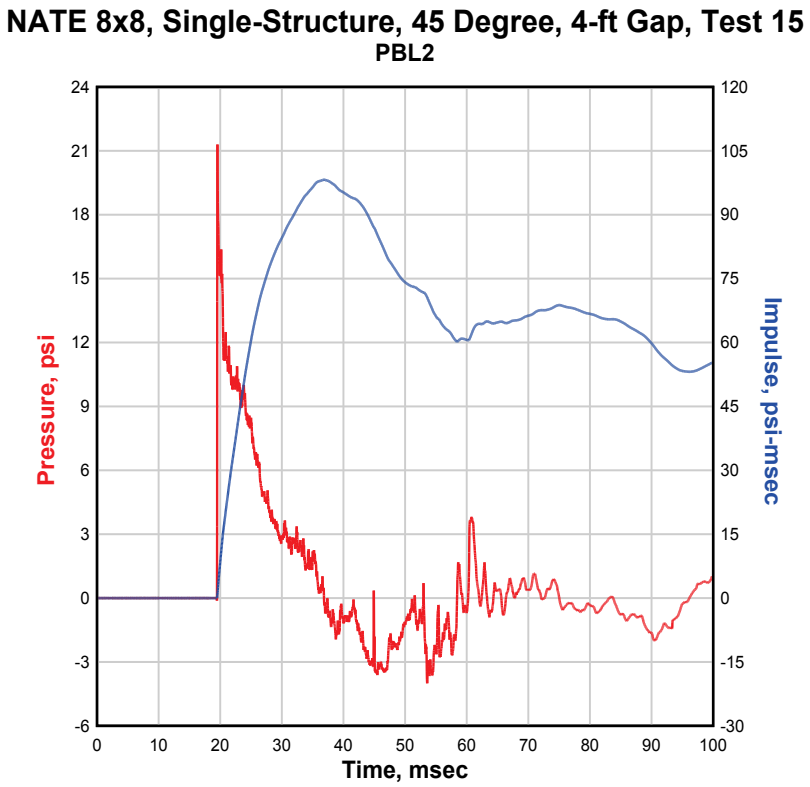

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
42
36
30
24
18
12
6
0
-6
-12
-18
0
10
20
30
40
50
60
70
80
90
100

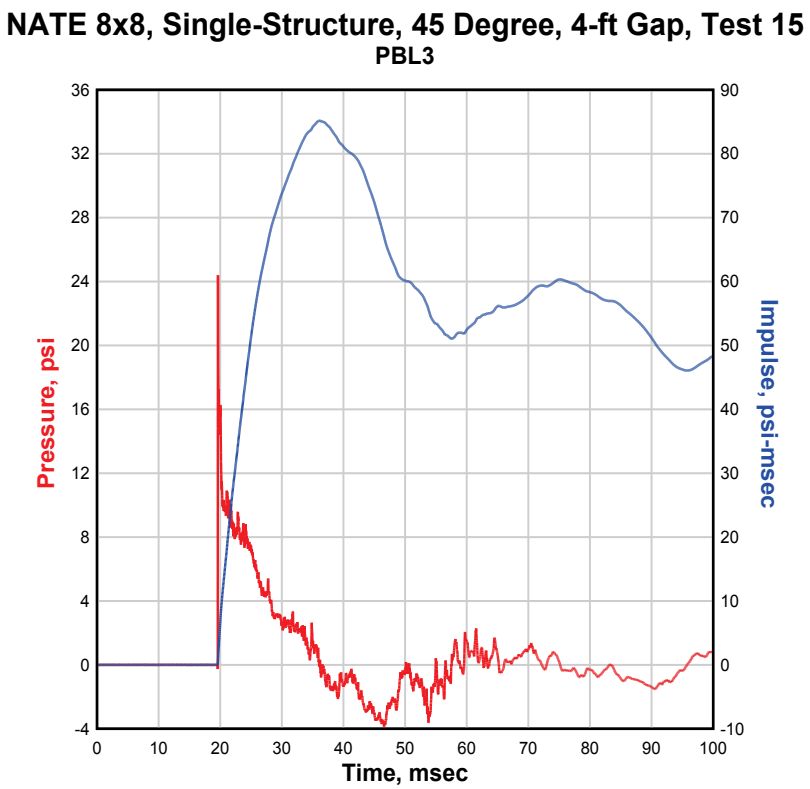

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
20
10
0
-10
-20
-30
-40
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
90
80
70
60
50
40
30
20
10
0
-10
0
10
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30
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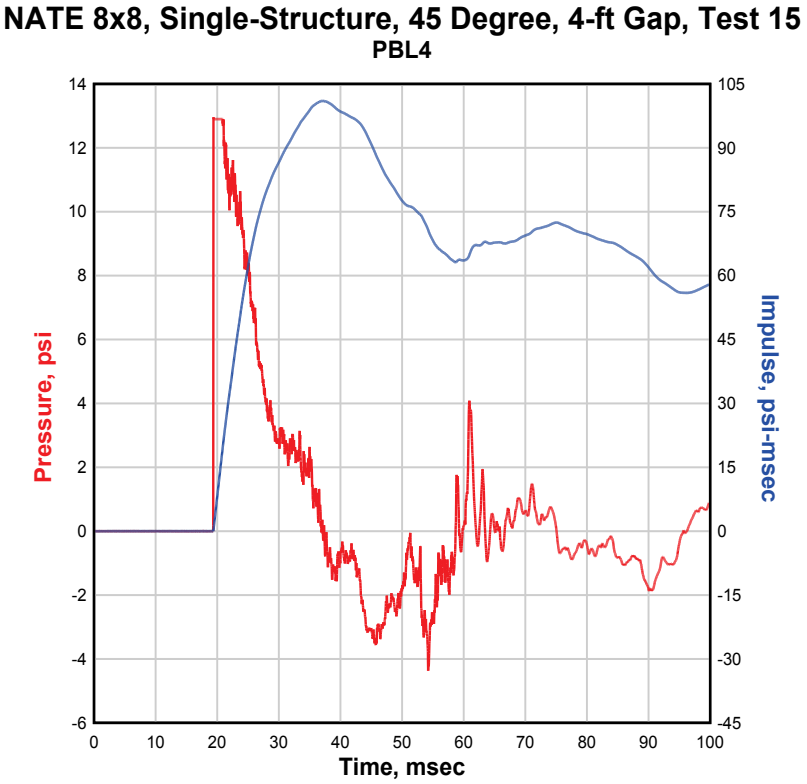
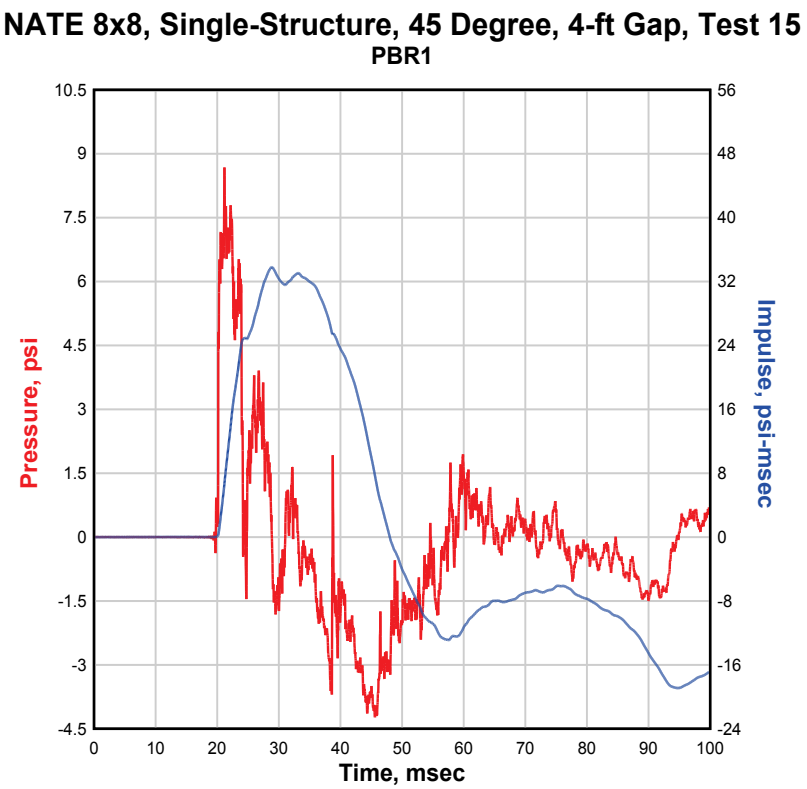
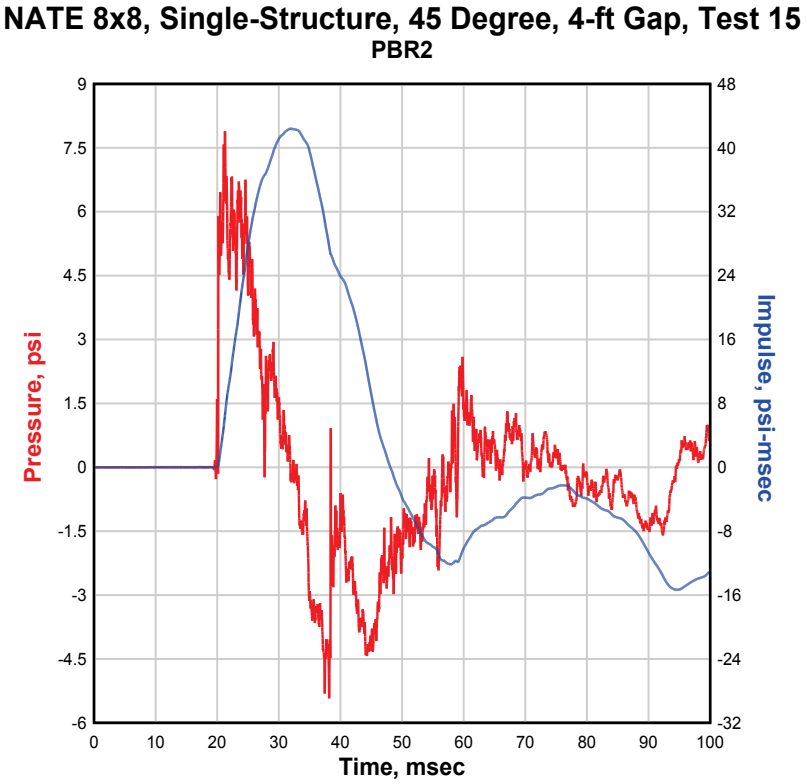
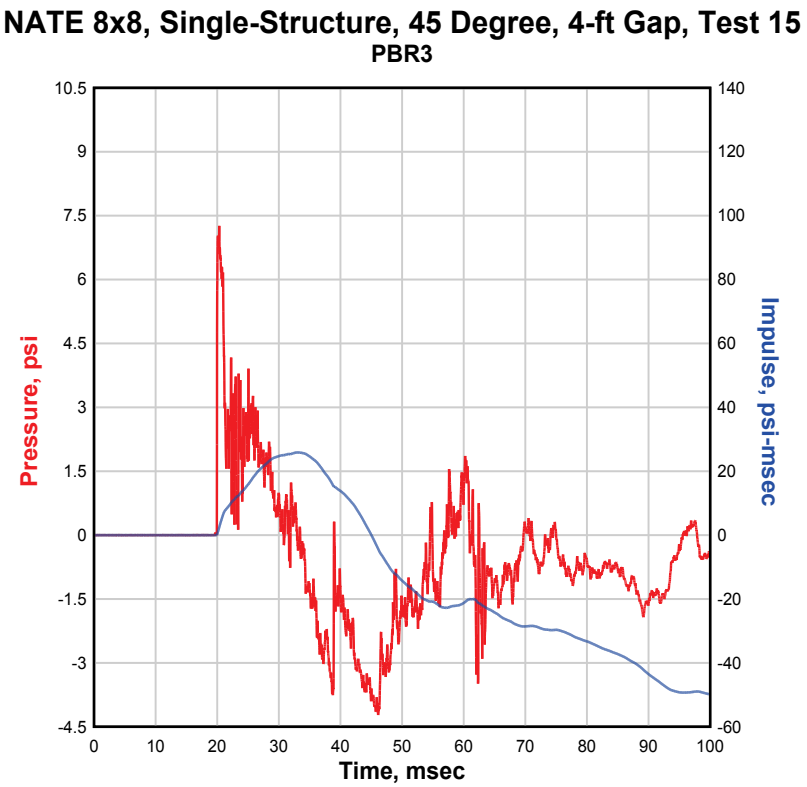
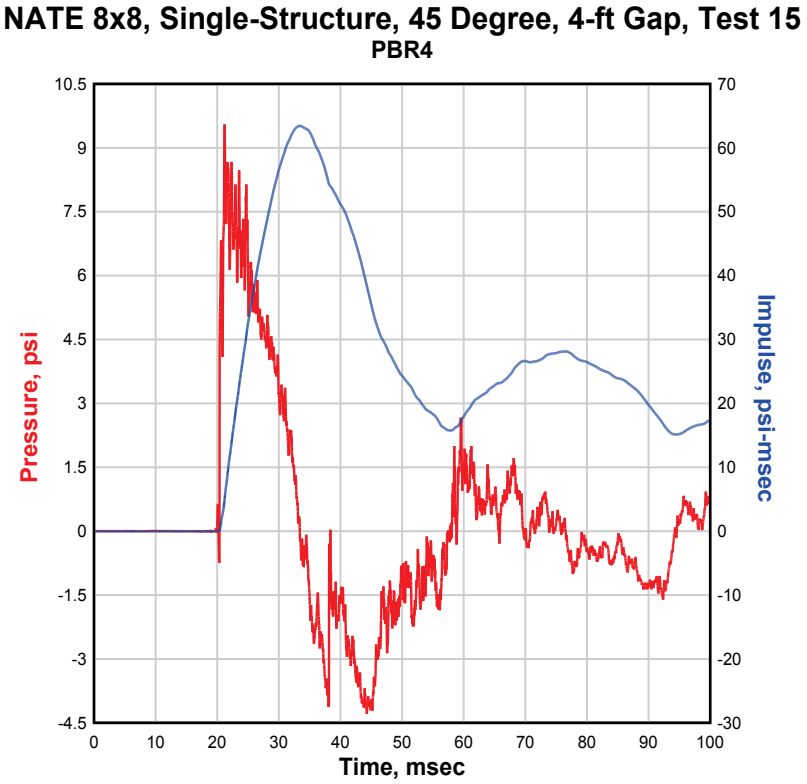
60
70
80
90
100

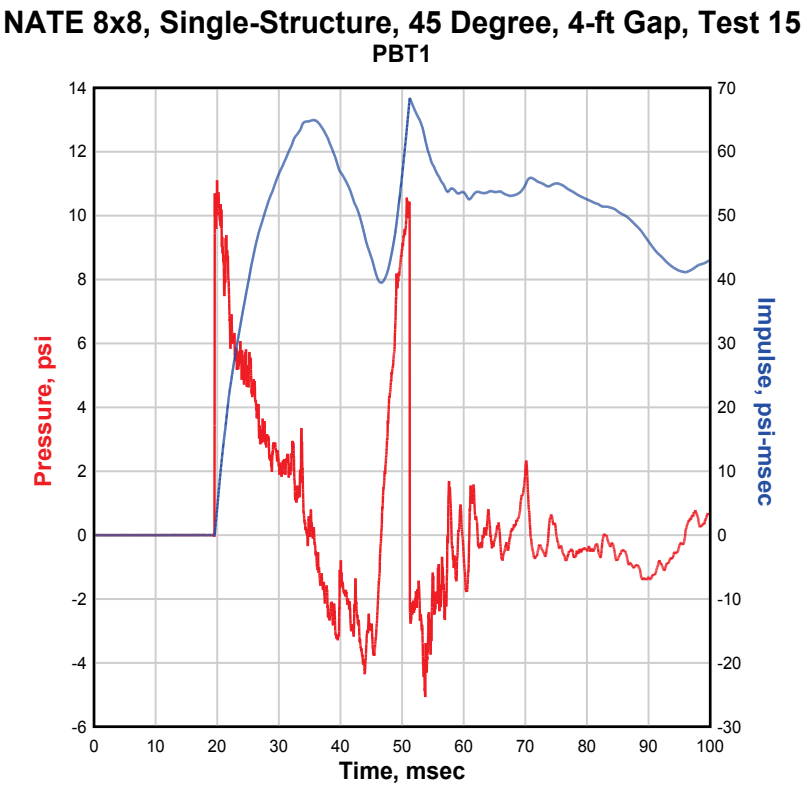

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

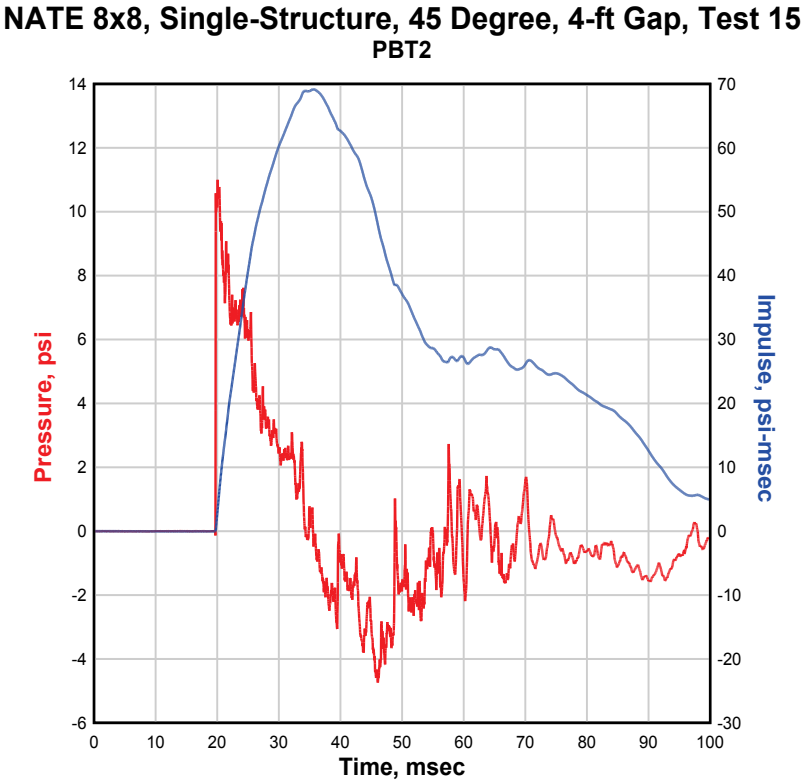

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
56
48
40
32
24
16
8
0
-8
-16
-24
0
10
20
30
40
50
60
70
80
90
100

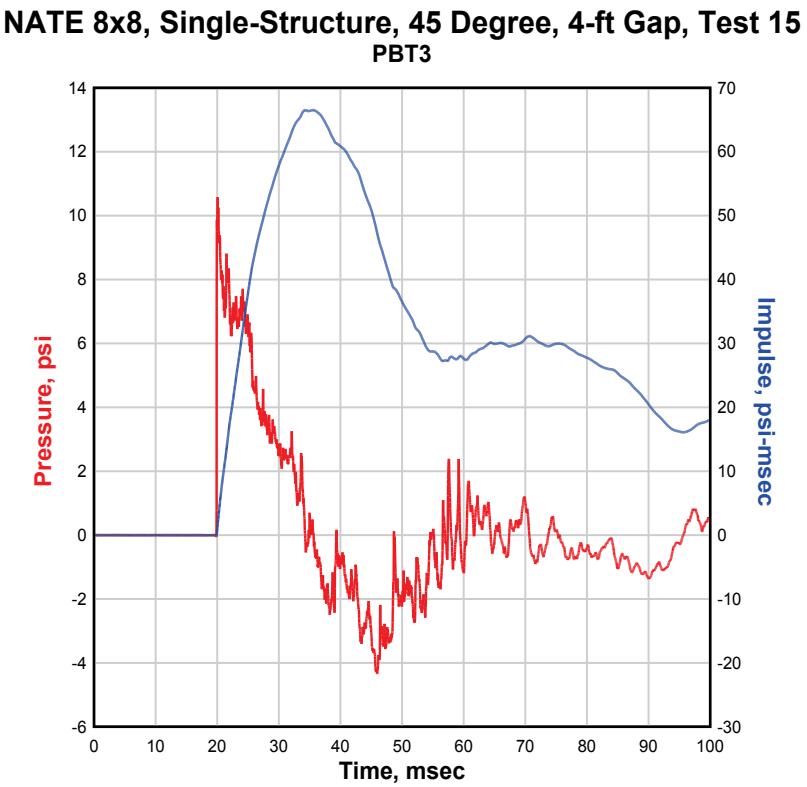

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100

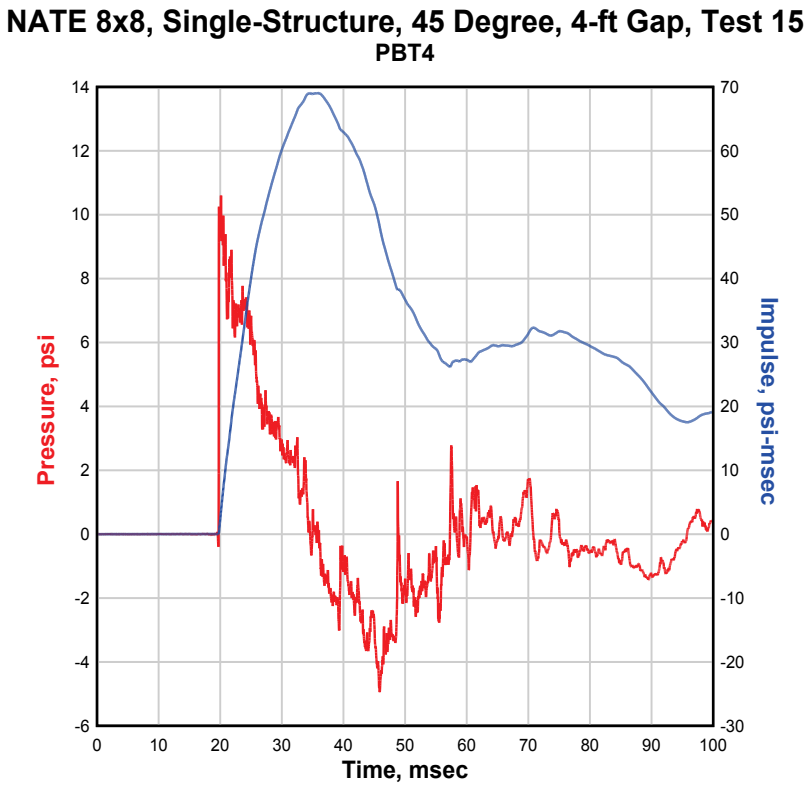

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
140
120
100
80
60
40
20
0
-20
-40
-60
0
10
20
30
40
50
60
70
80
90
100

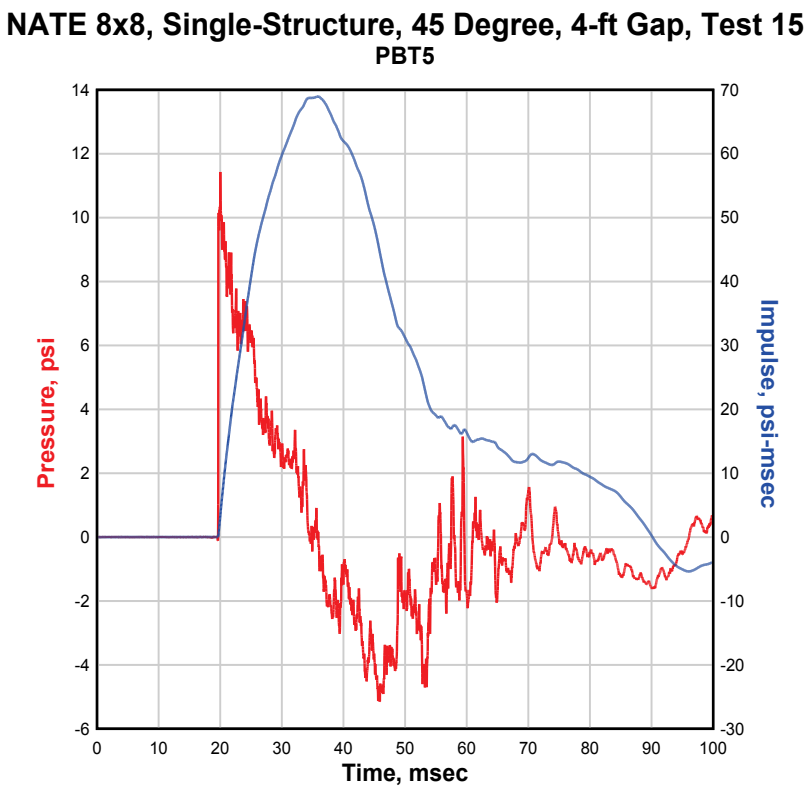

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

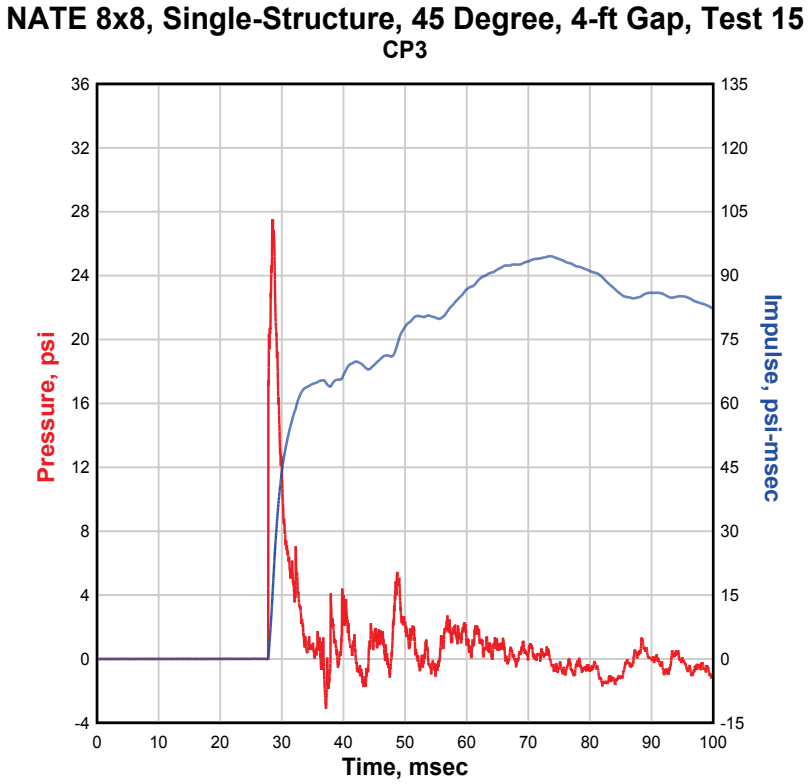

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

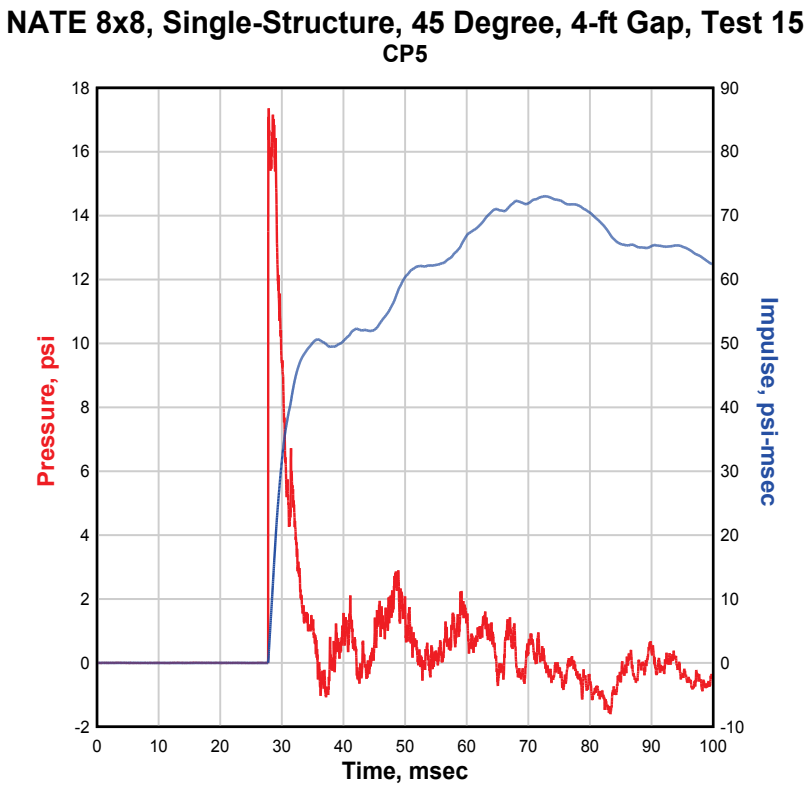

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

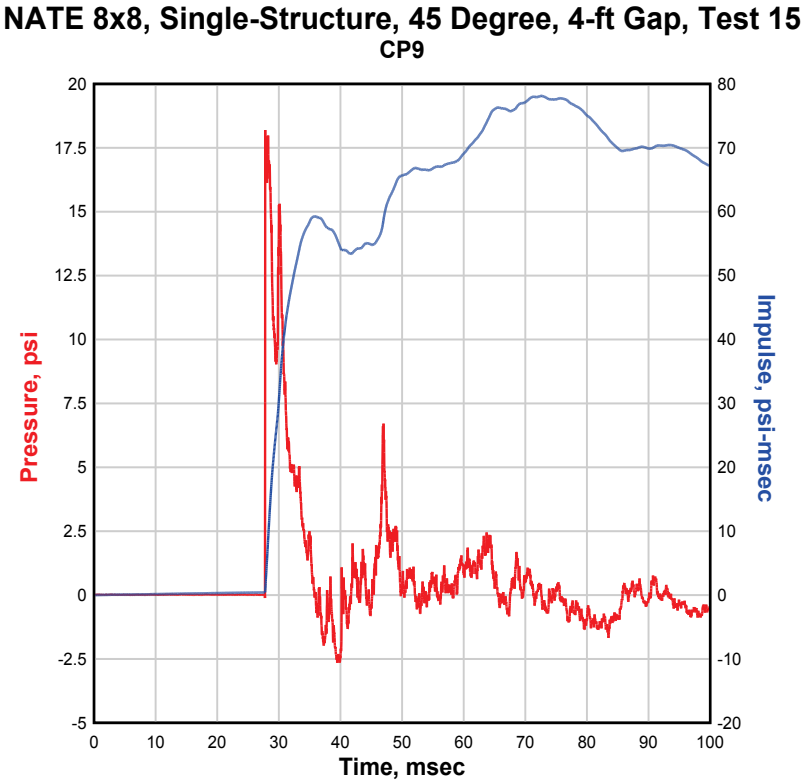

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

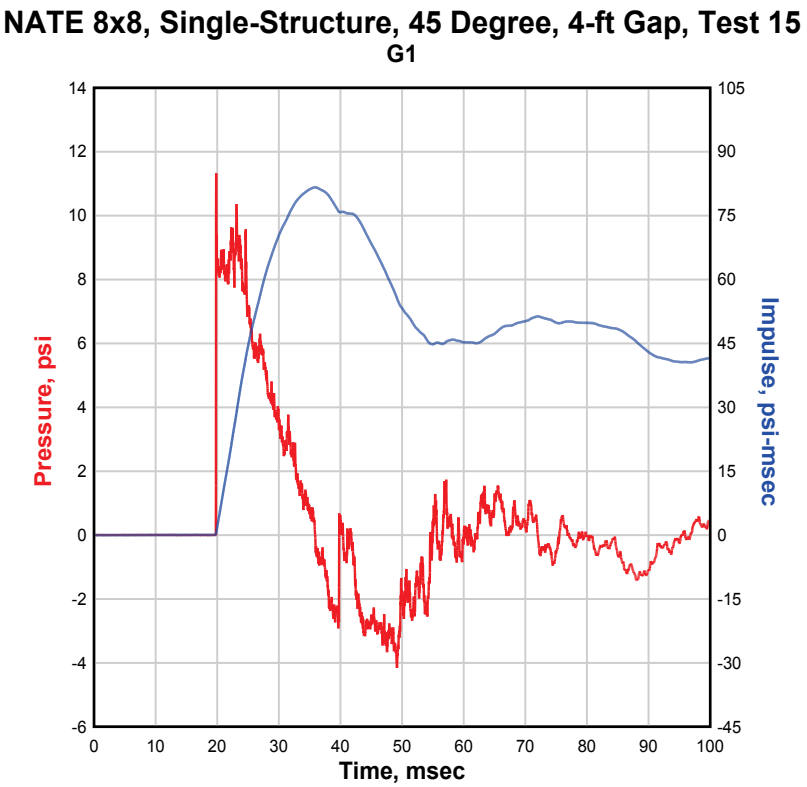

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

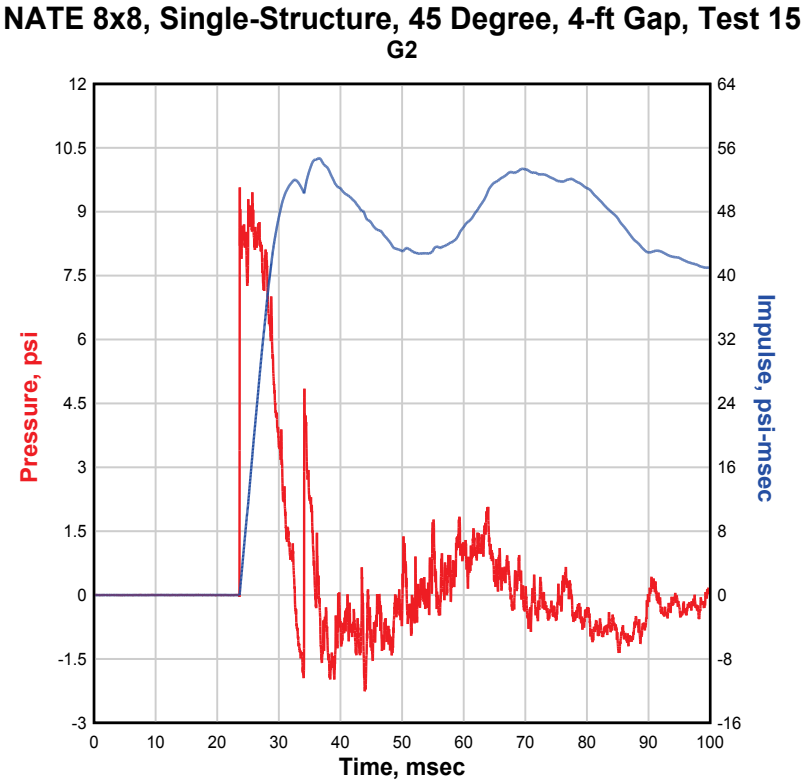

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100

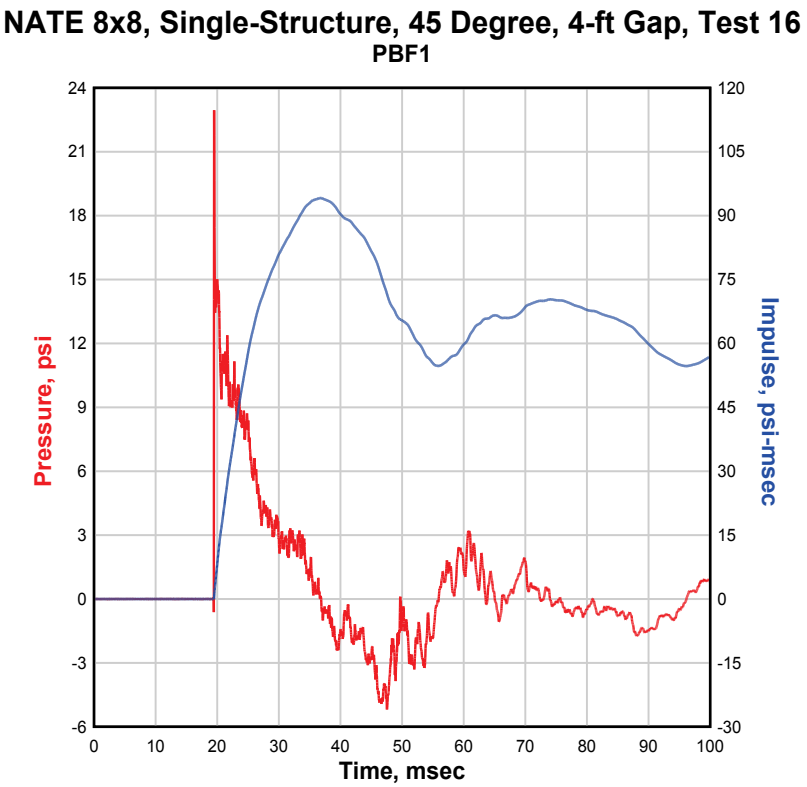

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
40
50
60
70
80
90
100

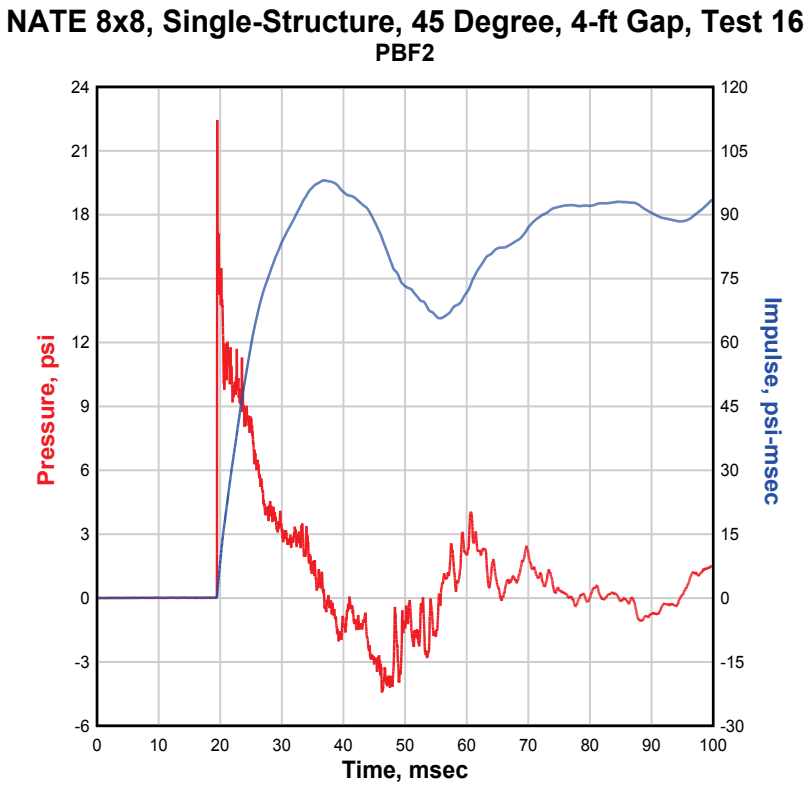

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
CP5
Pressure, psi
Impulse, psi-msec
Time, msec
18
16
14
12
10
8
6
4
2
0
-2
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

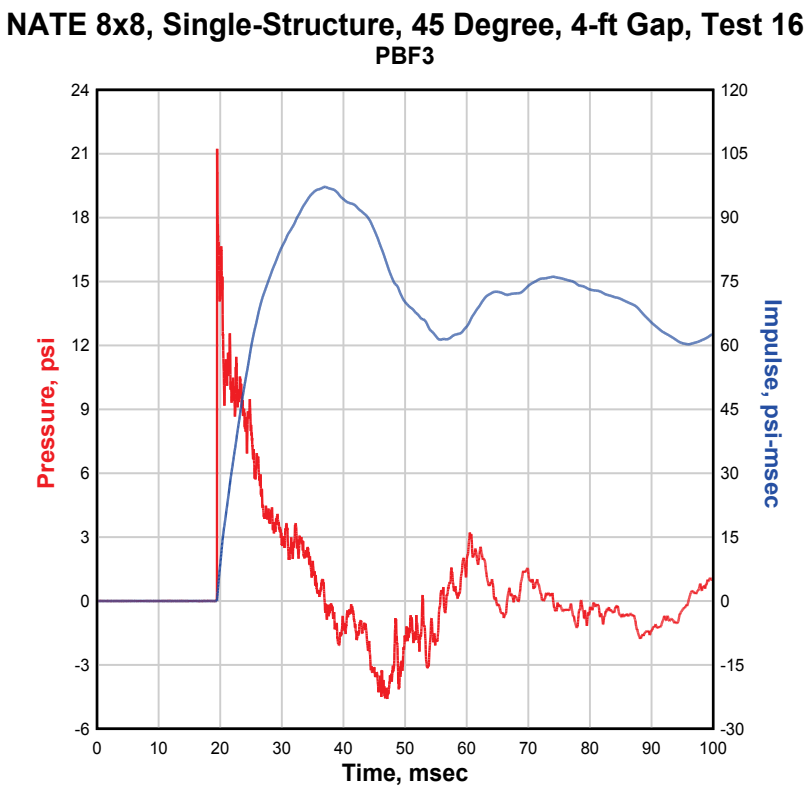

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
80
70
60
50
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100

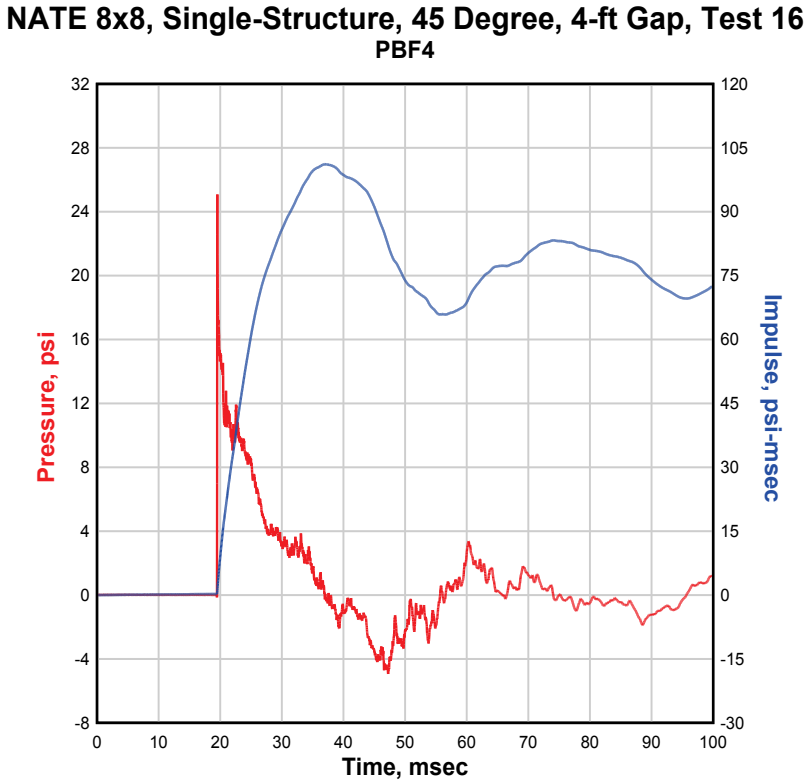

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
G1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
105
90
75
60
45
30
15
0
-15
-30
-45
0
10
20
30
40
50
60
70
80
90
100

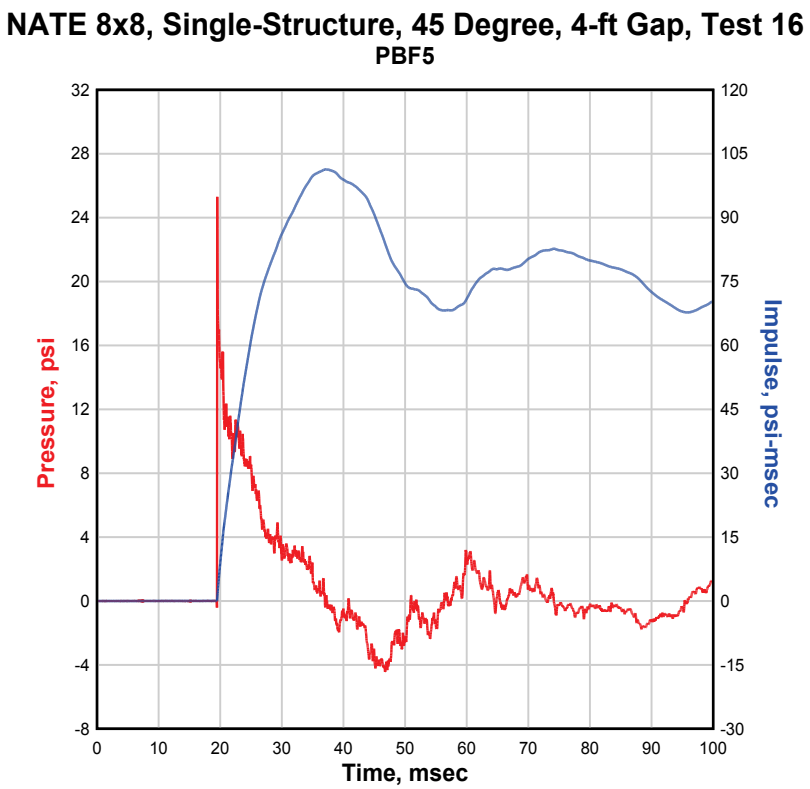

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 15
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
40
32
24
16
8
0
-8
-16
0
10
20
30
40
50
60
70
80
90
100

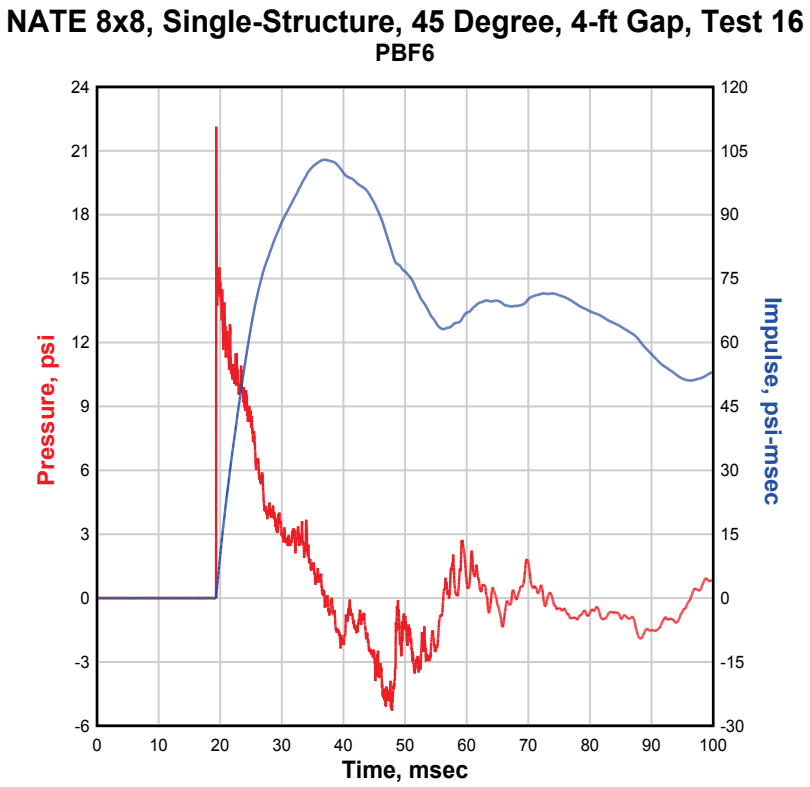

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBF1
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

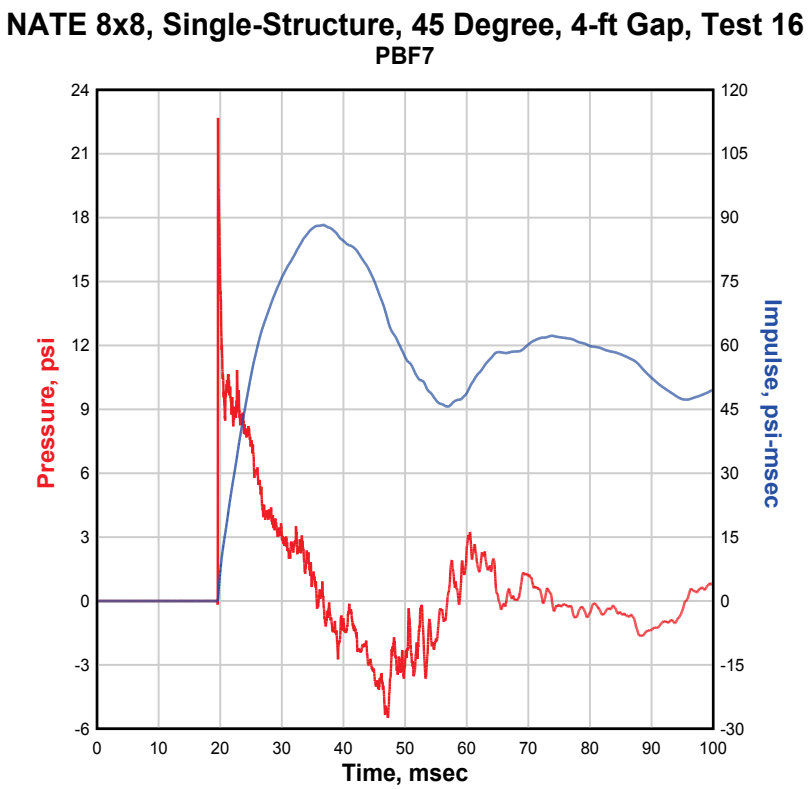

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBF2
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100

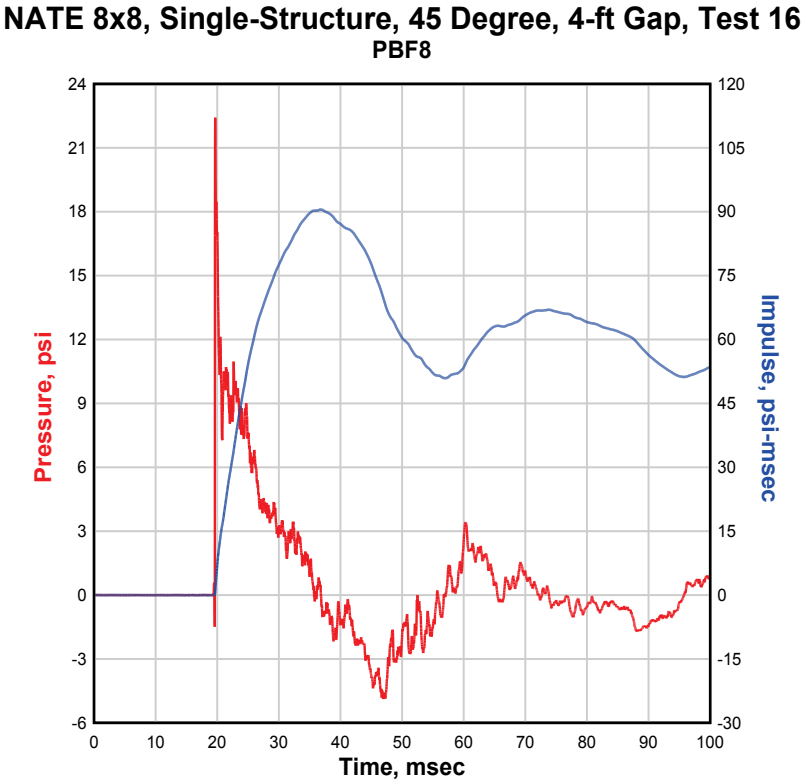

NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBF3
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBF4
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBF5
Pressure, psi
Impulse, psi-msec
Time, msec
32
28
24
20
16
12
8
4
0
-4
-8
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBF6
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBF7
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBF8
Pressure, psi
Impulse, psi-msec
Time, msec
24
21
18
15
12
9
6
3
0
-3
-6
120
105
90
75
60
45
30
15
0
-15
-30
0
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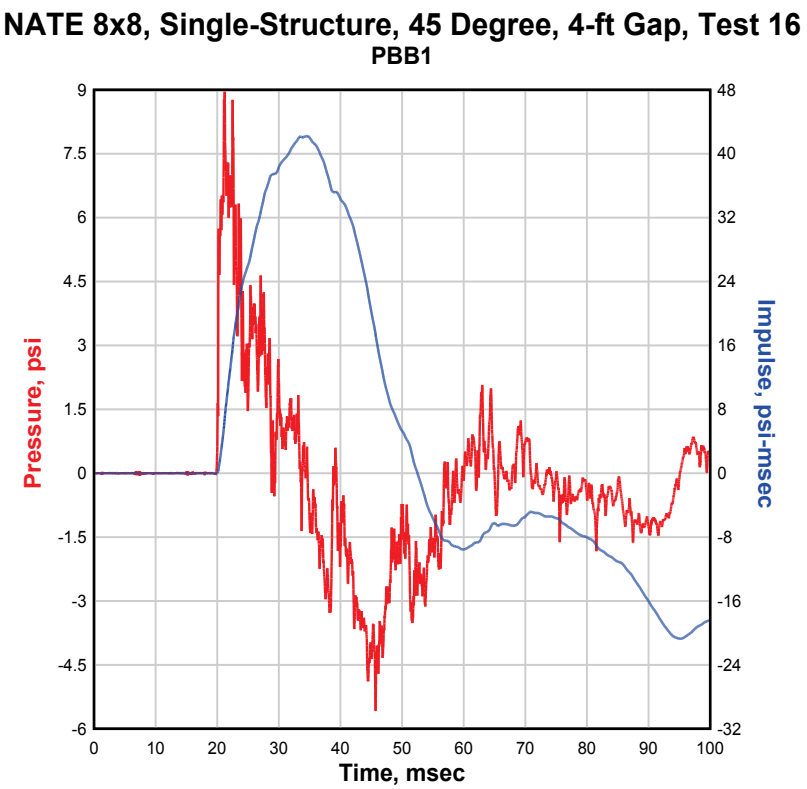
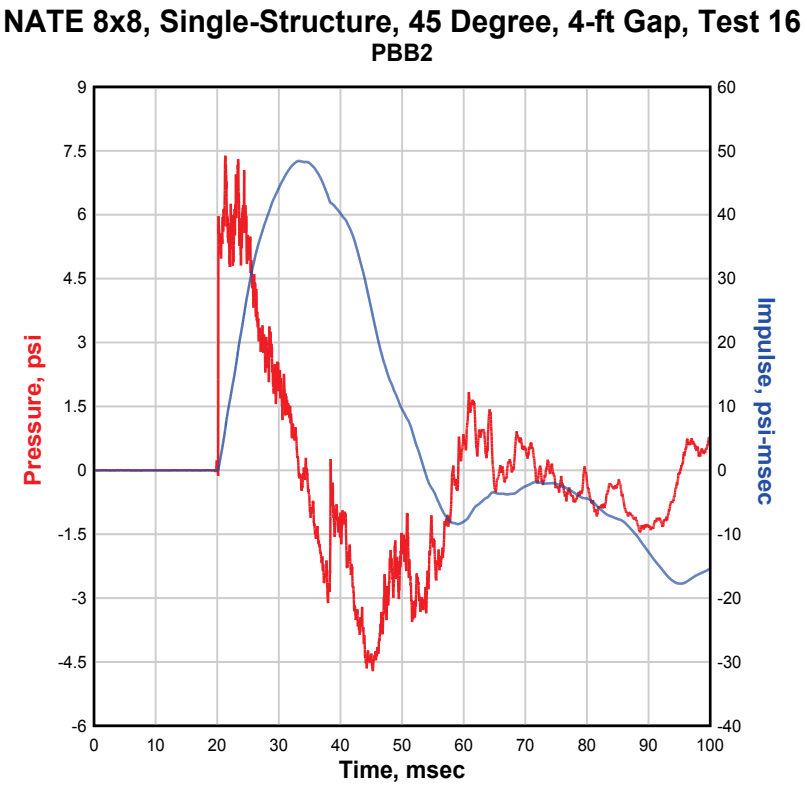
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBB1
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
16
8
0
-8
-16
-24
-32
0
10
20
30
40
50
60
70
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBB2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
30
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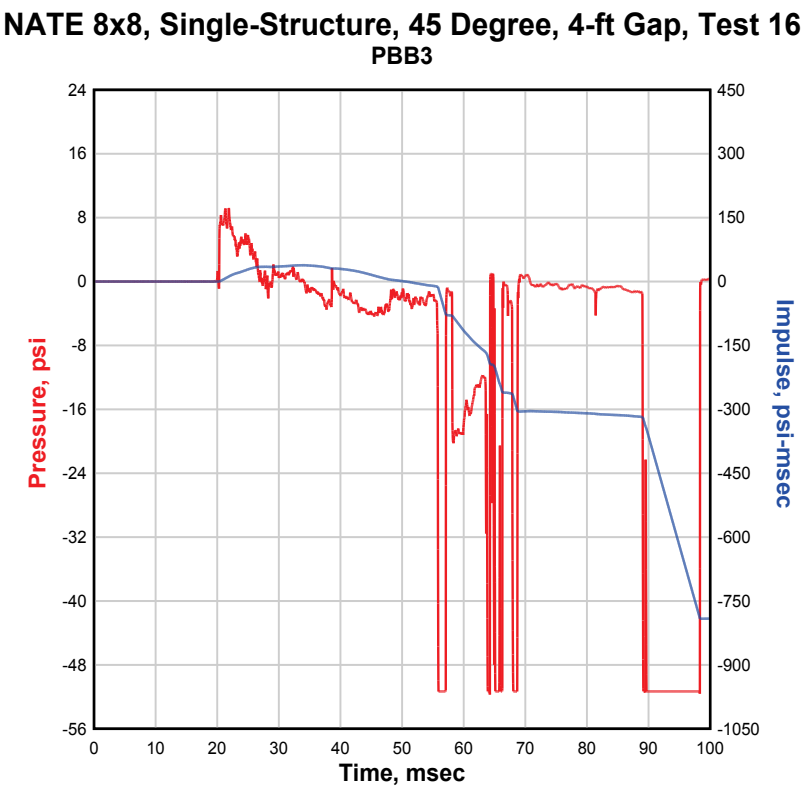
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBB3
Pressure, psi
Impulse, psi-msec
Time, msec
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
450
300
150
0
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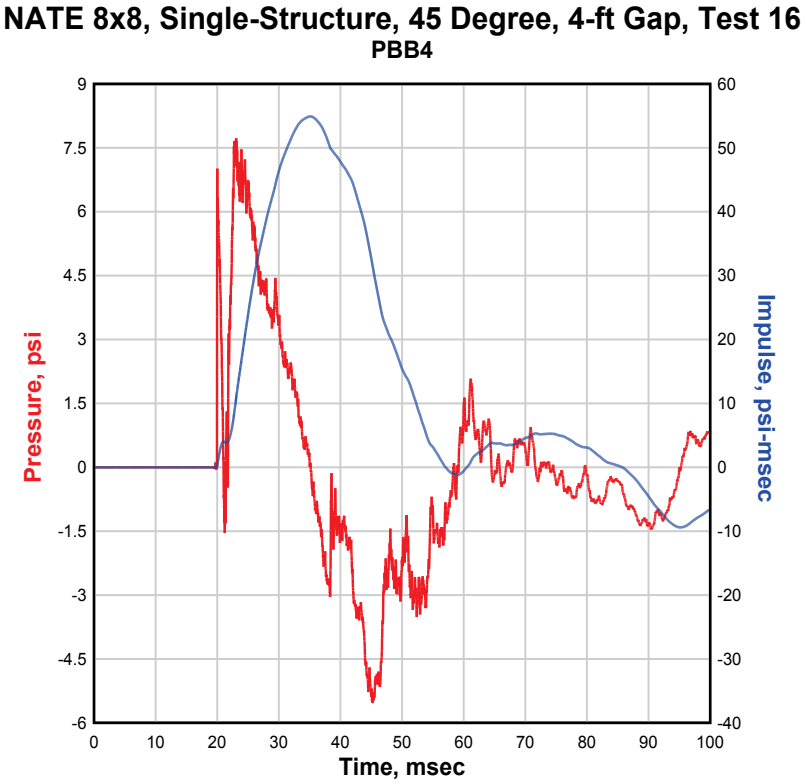
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBB4
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
60
50
40
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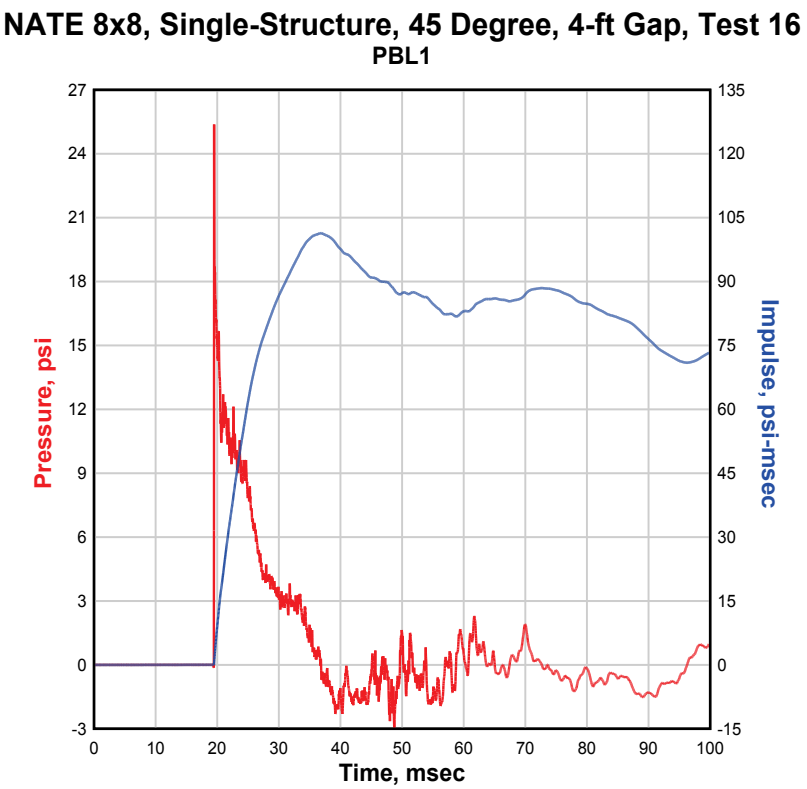
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBL1
Pressure, psi
Impulse, psi-msec
Time, msec
27
24
21
18
15
12
9
6
3
0
-3
135
120
105
90
75
60
45
30
15
0
-15
0
10
20
30
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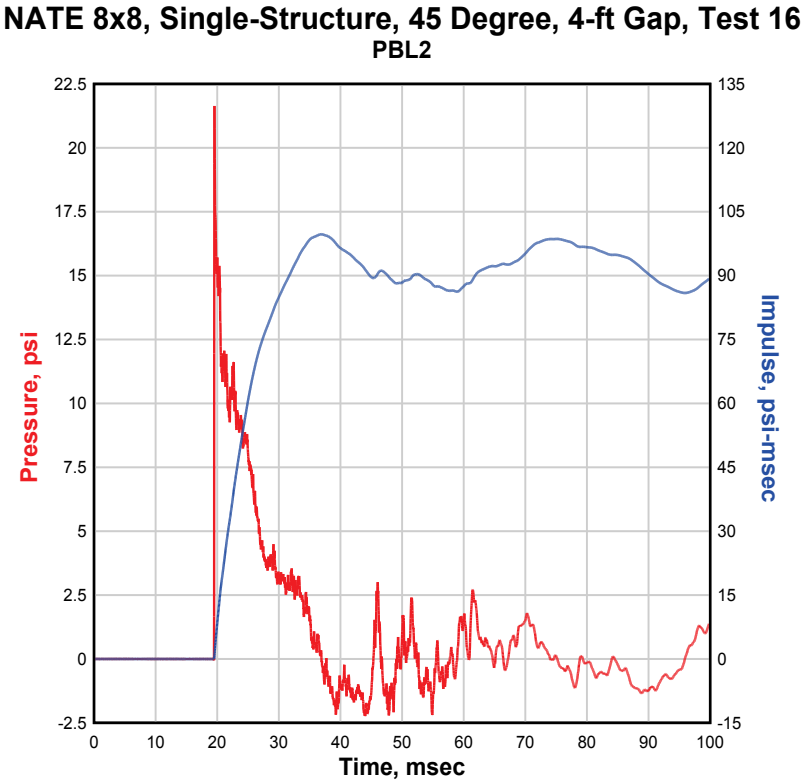
80
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBL2
Pressure, psi
Impulse, psi-msec
Time, msec
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
135
120
105
90
75
60
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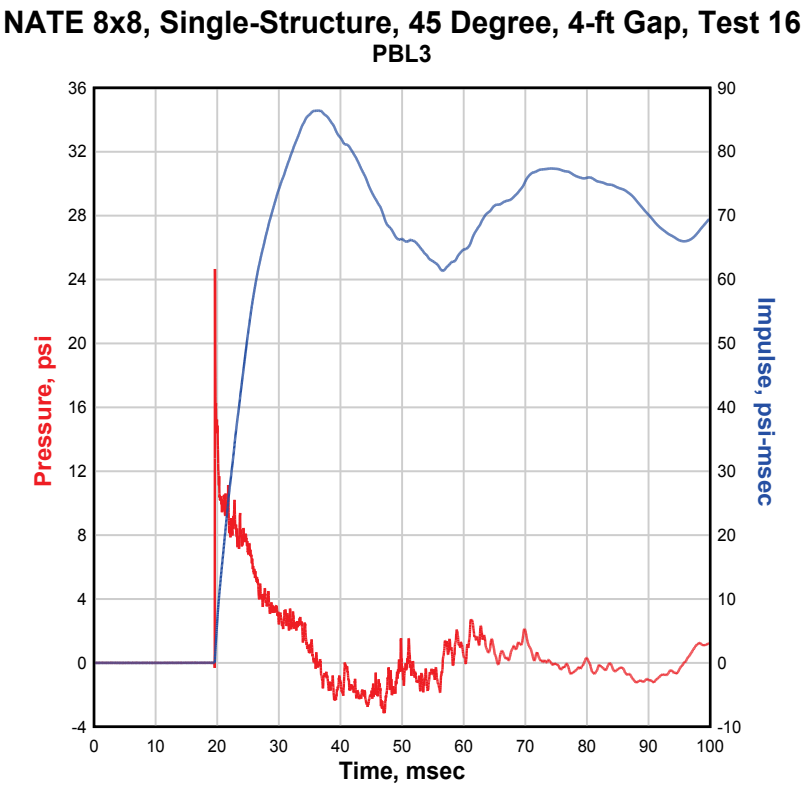
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBL3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
90
80
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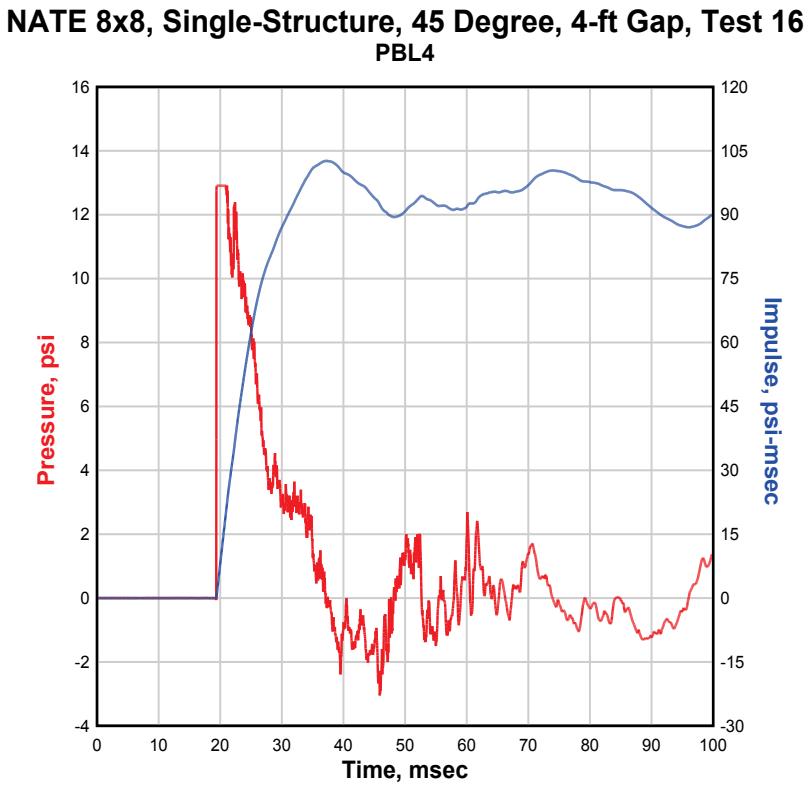
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBL4
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
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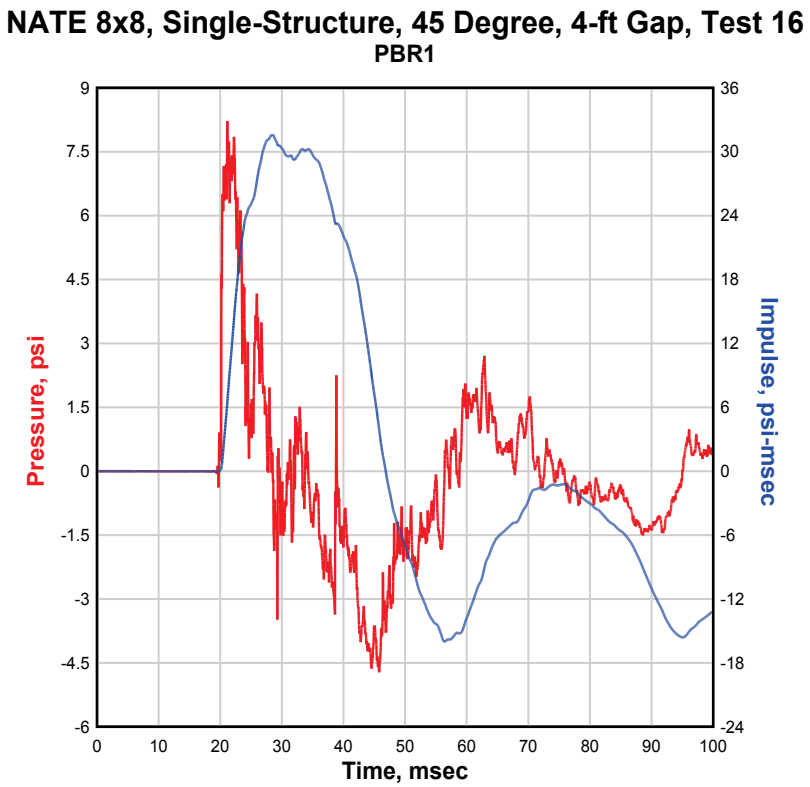
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBR1
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
36
30
24
18
12
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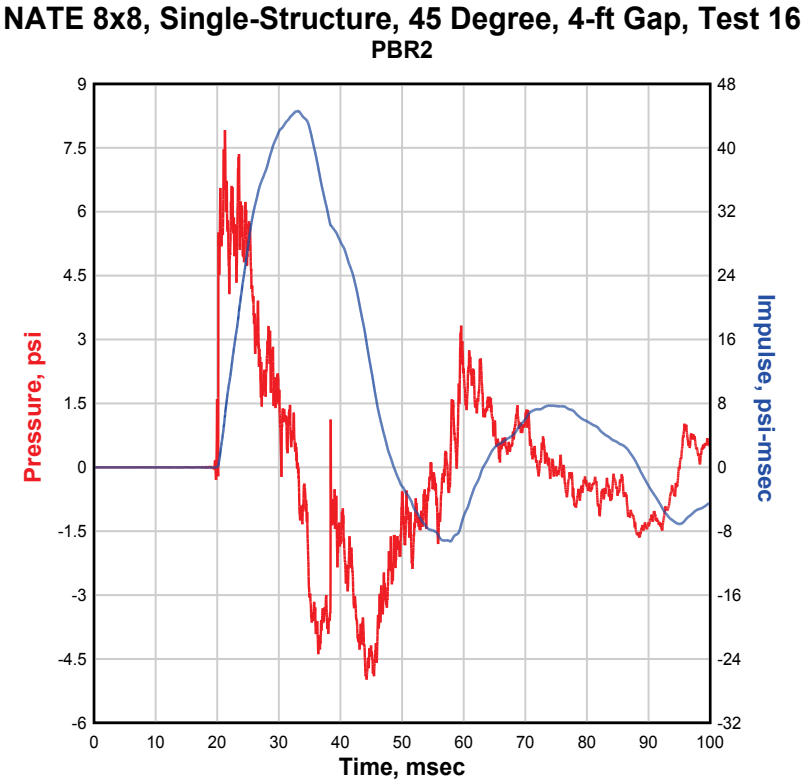
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBR2
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
48
40
32
24
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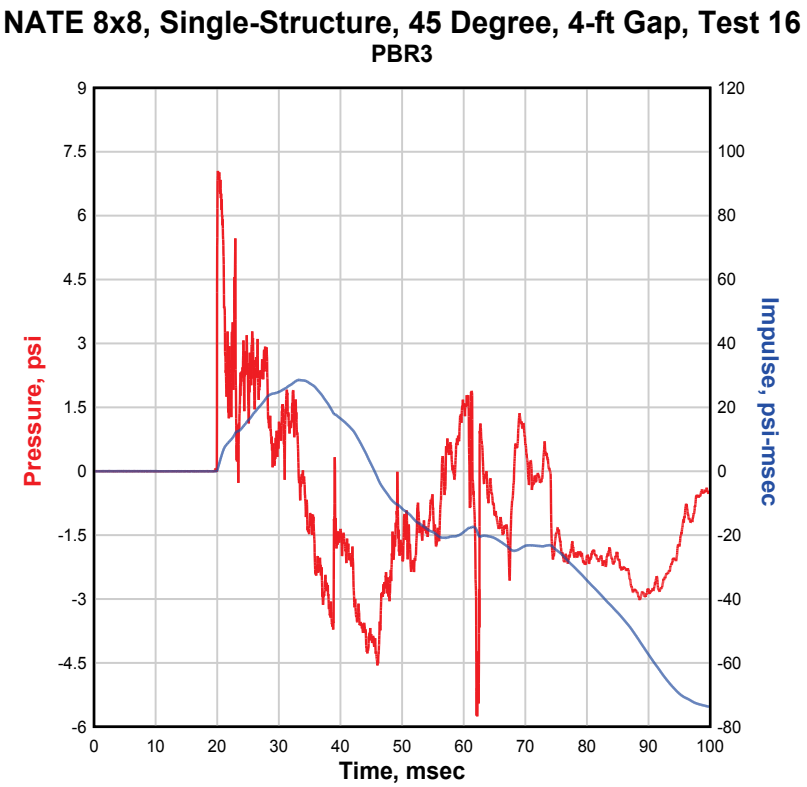
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBR3
Pressure, psi
Impulse, psi-msec
Time, msec
9
7.5
6
4.5
3
1.5
0
-1.5
-3
-4.5
-6
120
100
80
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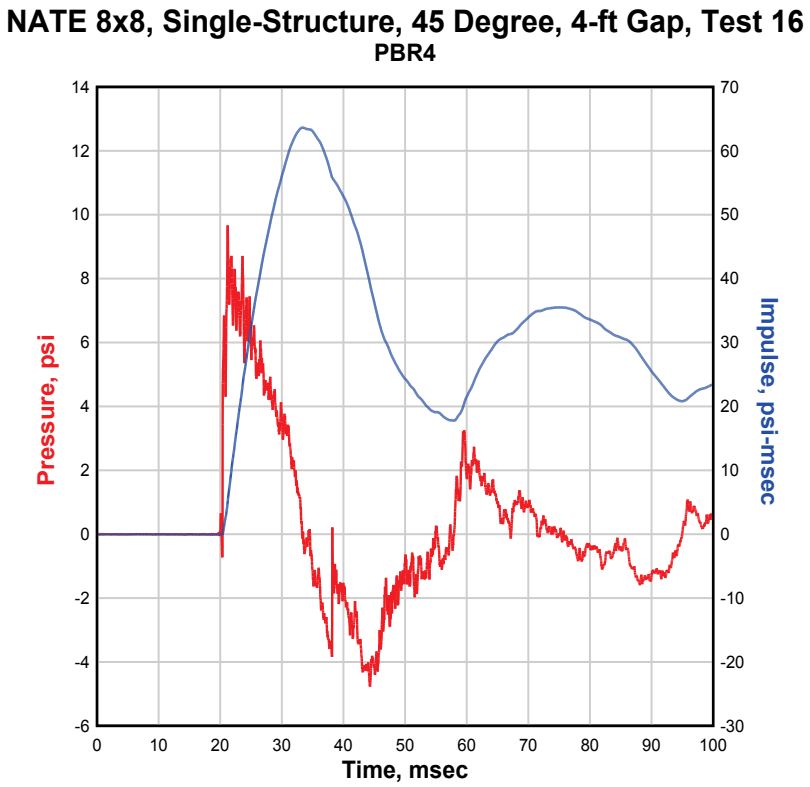
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBR4
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
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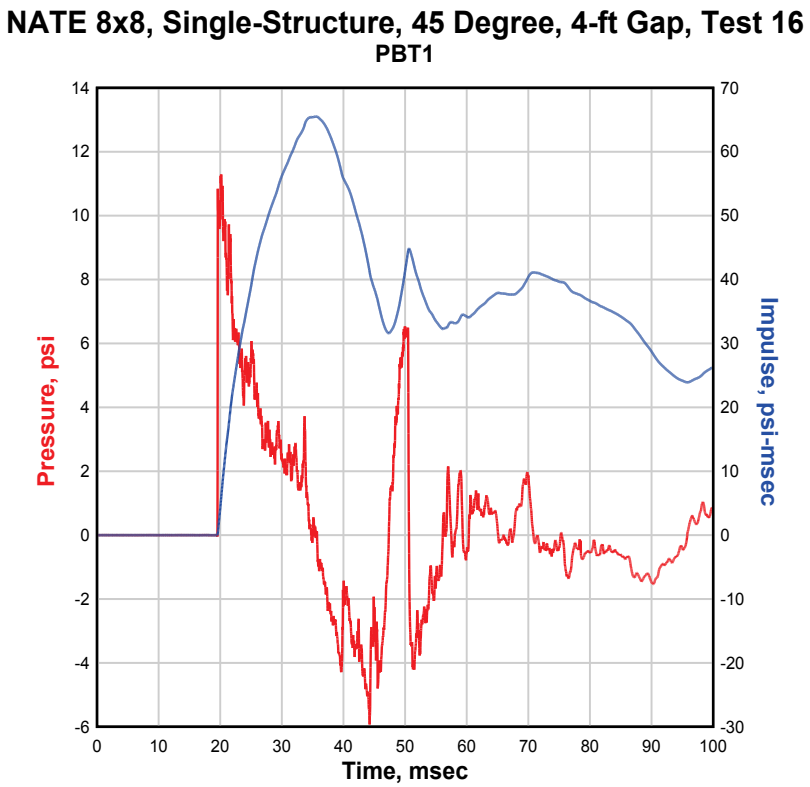
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBT1
Pressure, psi
Impulse, psi-msec
Time, msec
14
12
10
8
6
4
2
0
-2
-4
-6
70
60
50
40
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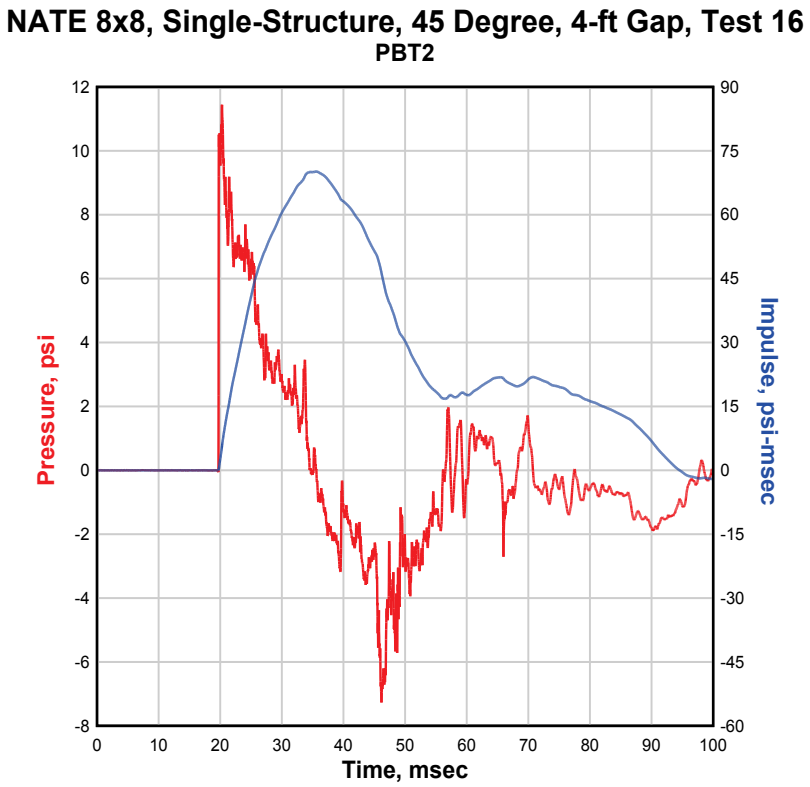
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBT2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
90
75
60
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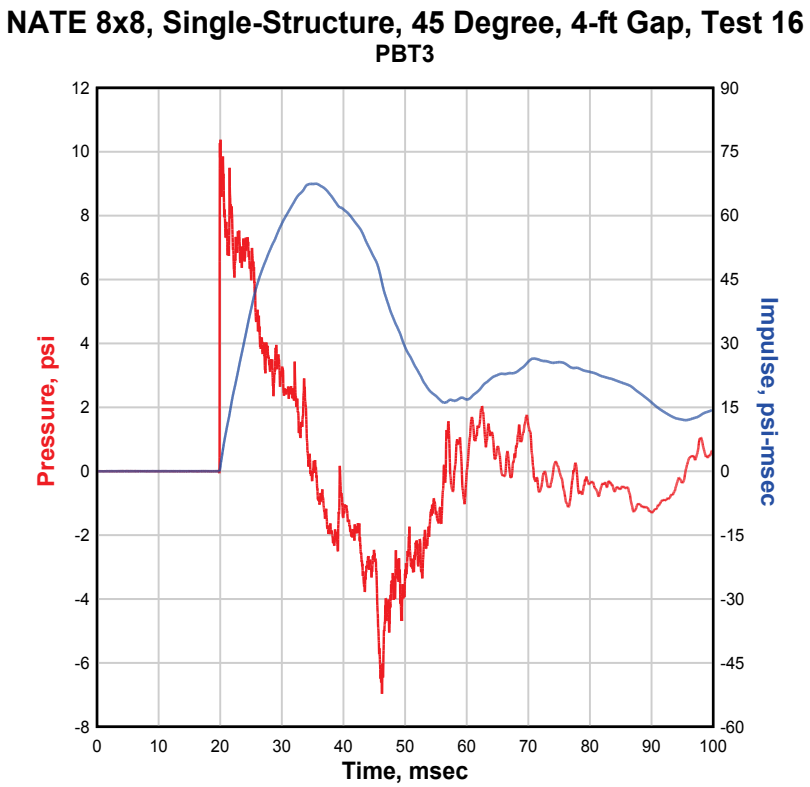
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBT3
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
90
75
60
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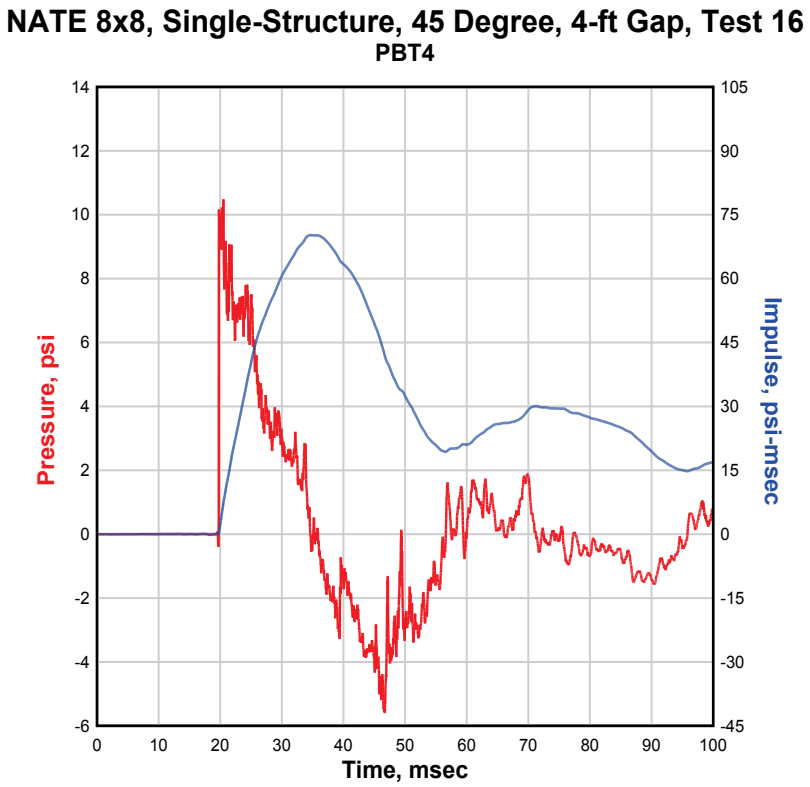
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBT4
Pressure, psi
Impulse, psi-msec
Time, msec
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12
10
8
6
4
2
0
-2
-4
-6
105
90
75
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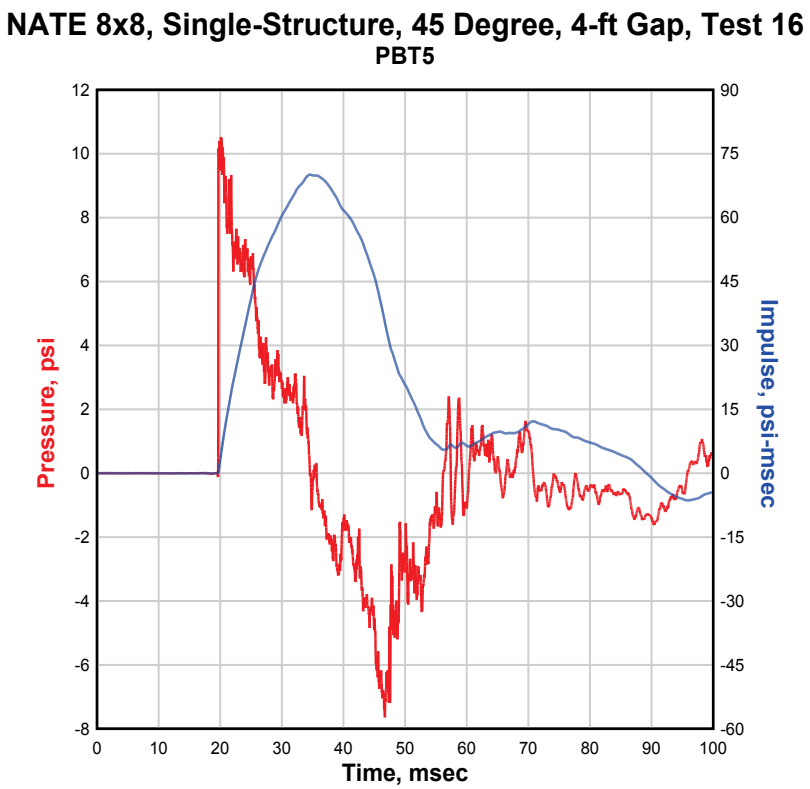
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
PBT5
Pressure, psi
Impulse, psi-msec
Time, msec
12
10
8
6
4
2
0
-2
-4
-6
-8
90
75
60
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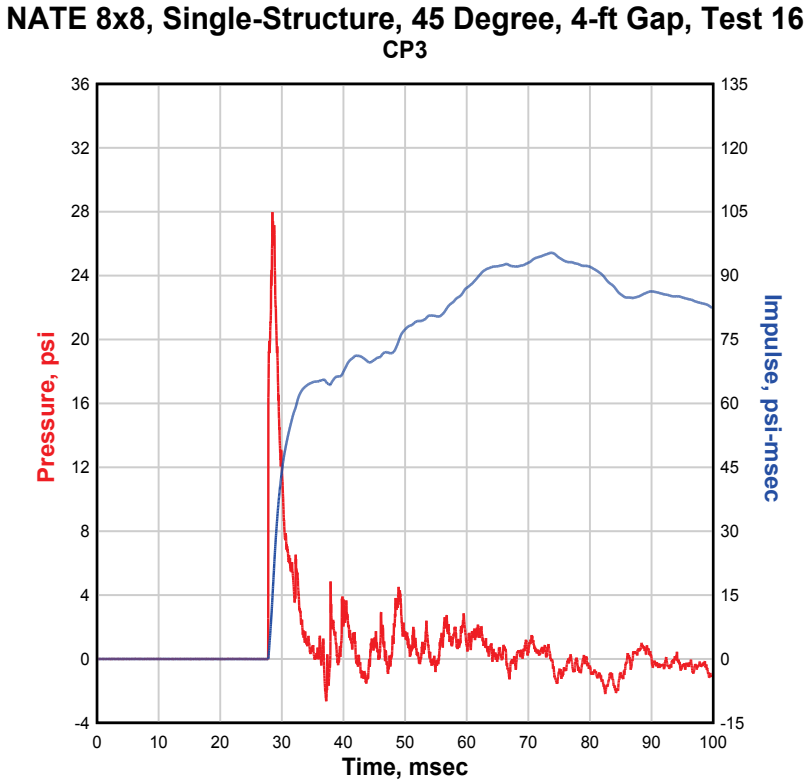
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
CP3
Pressure, psi
Impulse, psi-msec
Time, msec
36
32
28
24
20
16
12
8
4
0
-4
135
120
105
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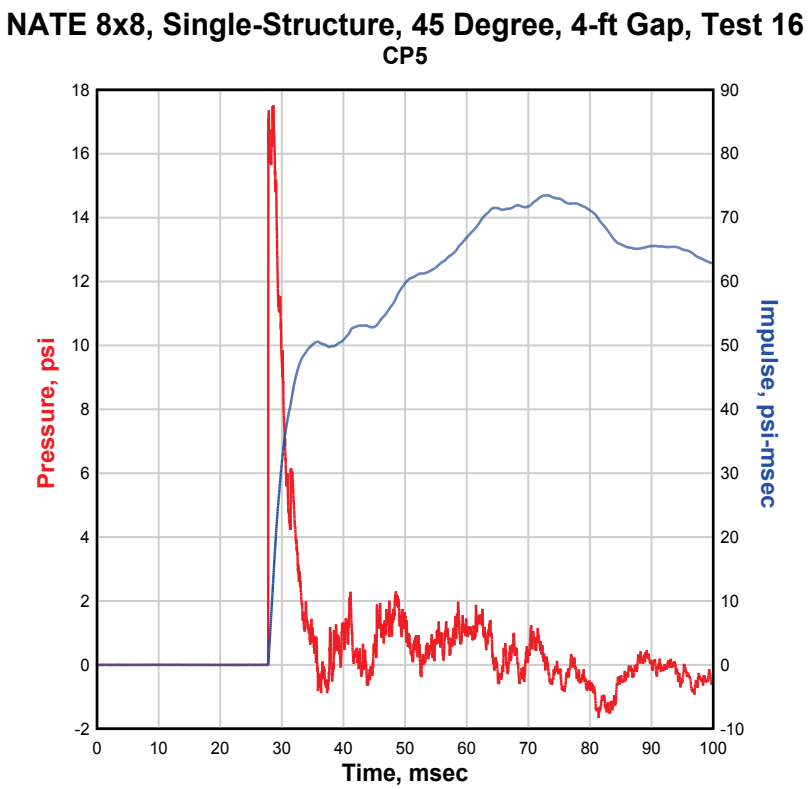
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CP5
Pressure, psi
Impulse, psi-msec
Time, msec
18
16
14
12
10
8
6
4
2
0
-2
90
80
70
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50
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70
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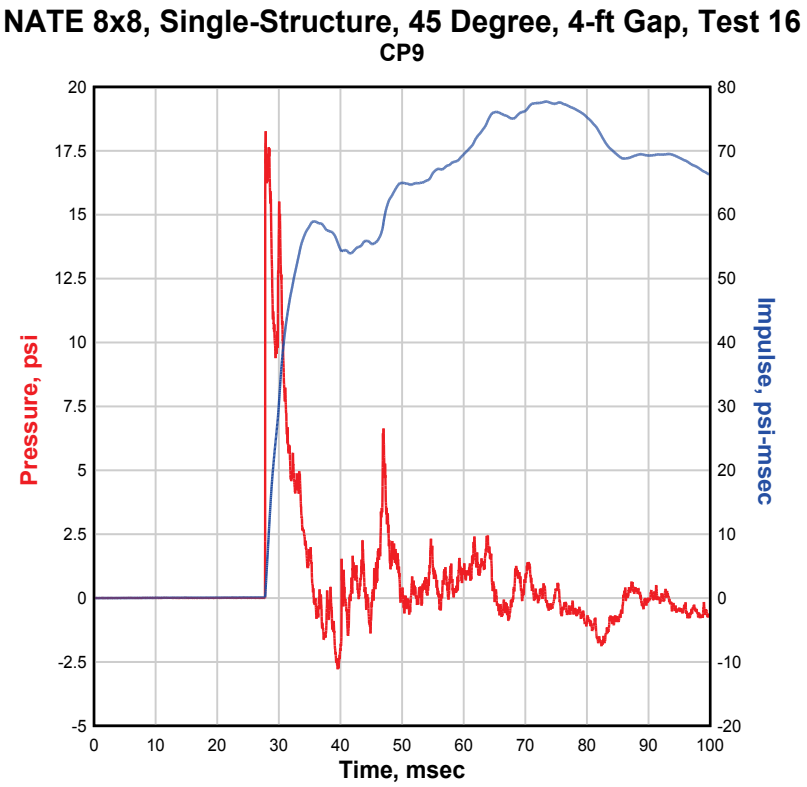
90
100


NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
CP9
Pressure, psi
Impulse, psi-msec
Time, msec
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17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
80
70
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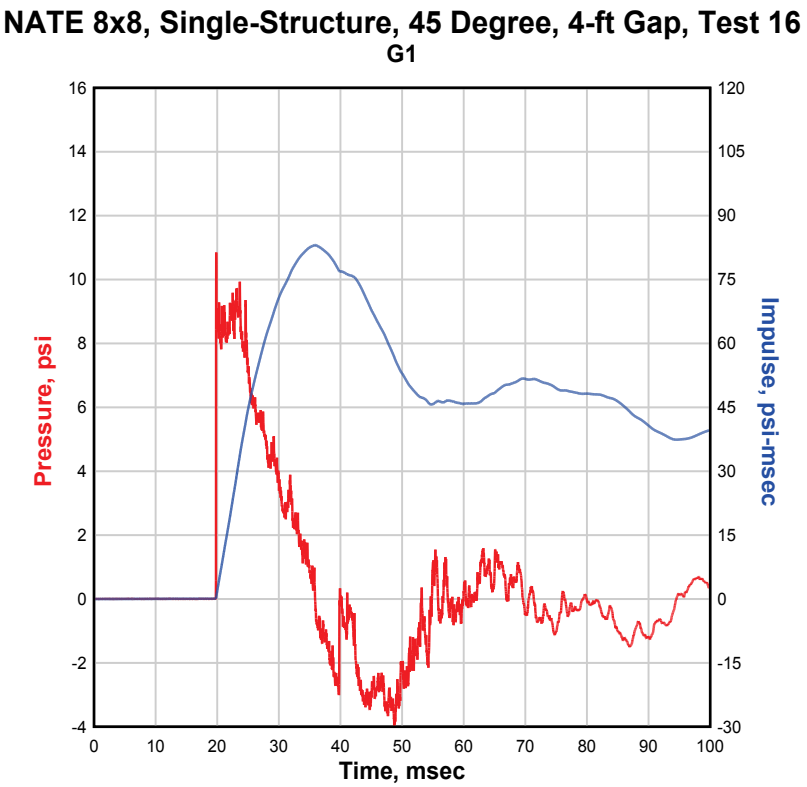
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
G1
Pressure, psi
Impulse, psi-msec
Time, msec
16
14
12
10
8
6
4
2
0
-2
-4
120
105
90
75
60
45
30
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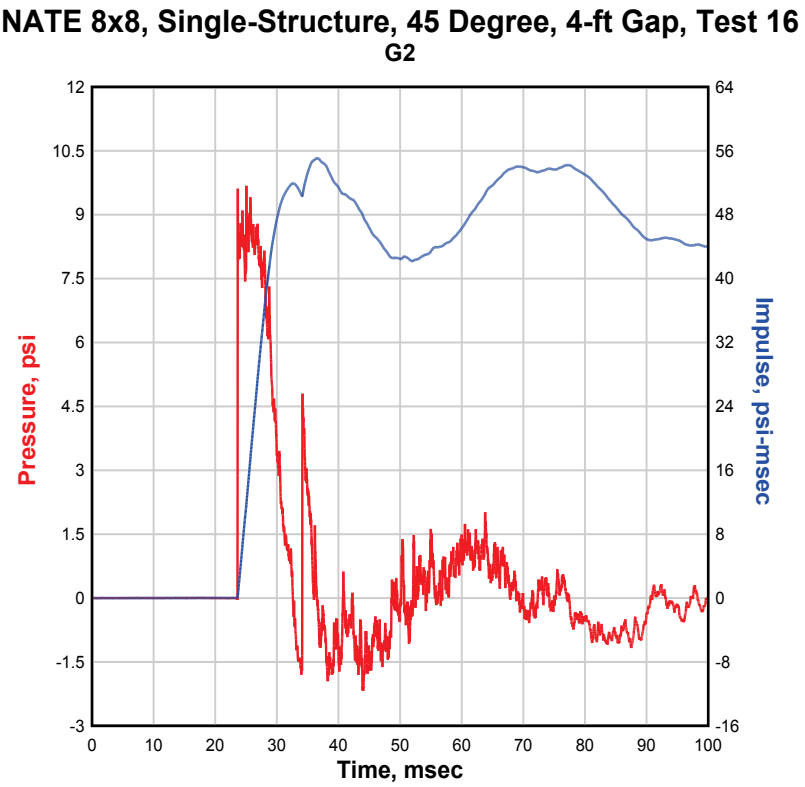
NATE 8x8, Single-Structure, 45 Degree, 4-ft Gap, Test 16
G2
Pressure, psi
Impulse, psi-msec
Time, msec
12
10.5
9
7.5
6
4.5
3
1.5
0
-1.5
-3
64
56
48
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32
24
16
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20
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100

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Department of Defense needs the capability to accurately predict airblast environments produced by explosive detonations and their interaction with geometrically complex objects that create complex flow fields, such as buildings, bridges, dams, etc. First-principles computer codes are typically used to generate high-fidelity simulations of these explosive events and their effects. These codes are continuously improving, but still require validation against experimental data to establish confidence in the results produced by the simulations. This report describes a set of replicate experiments in which a small, non-responding steel box-type structure was installed at varying obliquities and subjected to a simulated blast loading in a Blast Load Simulator (BLS) to provide pressure-time data at several locations on the surfaces of the structure. The BLS is a highly tunable, compressed-gas-driven, closed-end shock tube designed to simulate blast waveforms for explosive yields up to 20,000 lb of TNT equivalent at a peak reflected pressure up to 80 psi and a peak reflected impulse up to 1,100 psi-msec. Pressure and impulse waveforms are presented, and comparisons were made among the replicated experiments to evaluate repeatability. The uncertainty in the experimental pressures and impulses was evaluated by computing 95% confidence intervals on the results.

15. SUBJECT TERMS

Airblast
Verification and validation
Blast effect – Testing
Blast Load Simulator
First Principles Codes
Detonation waves
Shock (Mechanics)
Shock tubes
Scientific apparatus and instruments
Pressure gages

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